Hand Book of Natural Gas

Harry L. Massen

HAND BOOK
OF
NATURAL GAS

BY

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MEMBER A. S. M. E. AND NATURAL GAS ASSOCIATION

SECOND EDITION

1915

PUBLISHED BY
METRIC METAL WORKS
ERIE, PENNSYLVANIA

Press of
ASHBY PRINTING CO.
Erie and Pittsburgh

PREFACE

THE need of a Hand Book containing authoritative information on High and Low Pressure Construction in the use of Natural Gas, and providing information and suggestions of a practical nature for those engaged in field work was wholly responsible for the publication of the first edition.

From the splendid reception accorded the first edition, the publisher feels that, with the additional information and data available, a carefully revised second edition is demanded. Some errors that crept into the first edition have been corrected and new tables with many pages of material hitherto unpublished broadens the scope of the work and brings it completely up to date.

Included are the tables, formulæ and data prepared by the late F. H. Oliphant, and which, for purposes of easy reference, are printed in connection with the subjects to which they apply

The constant aim throughout this work has been usefulness. No effort or expense has been spared to insure its data and information being accurate in every detail, and absolutely dependable.

The information presented is taken from the experience of the most active and successful operators in the business, as well as from the author's own practical experience. It is only from such data that a practical guide for practical men can be built.

The author and publisher make grateful acknowledgment of assistance generously given by gas men in every section of the country, and appreciatively thank every one who, by word, act or suggestion, has contributed to the betterment of this Hand Book.

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PART ONE

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In view of the many theories that have been advanced regarding the original source of natural gas, we herewith submit a paper written by the late Frank Westcott of Alden, New York, who made a life work of the study of natural gas from a geological standpoint. His observations were obtained from a study of rock formations as well as the logs of many gas wells throughout western New York, Pennsylvania, Ontario, Ohio and West Virginia, and several other states.

The paper is advanced to place before the gas fraternity a reasonable view, not only of the possible source of natural gas but also of the geological formation of the earth.

The Earth's Formation Briefly Told—"What we now call the earth was, in the beginning, a gaseous body or a molten chaotic mass probably thrown off by some planet, that through a long process of cooling gradually took shape as a globe with a thin hard crust.

The hard crust, which was of slight thickness in the beginning, but increasing as ages passed, was made up principally of granite formation commonly spoken of as the floor of the earth. At this period there was neither animal nor vegetable life existing, as the heat was too intense; gas and oil were out of the question.

The transformation from a gaseous body to a hard-crusted globe probably covered a period of many millions of years. During this period there were no mountains nor rivers and the earth had not begun to shrink.

As ages passed and the globe cooled sufficiently to allow precipitation of the vapor surrounding it, the Potsdam and the Trenton rocks began to form on top of the granite, in the order named. The earth began to shrink, and it was this shrinking of the crust, due to its loss of heat, that created the mountain ranges and the high elevated plateaus, and brought to the surface portions of the lower layers of the earth's crust, carrying with them the metals now being mined. Had this upheaval not taken place these metals could never have been reached.

The earth's crust is supposed to be from twenty-five to thirth-five miles thick. The increase of temperature toward the interior varies at different points on the globe as shown by tests made in mining shafts and deep wells. At Butte, Montana, the copper mining shafts show an increase of 1 deg. for each 52 feet descent. The average increase of temperature has shown 1 deg. fahr. for each 60 to 64 feet descent toward the center of the earth.

The cooling and shrinking of the earth is still going on, which accounts to some extent for the earthquakes, volcanic eruptions and other minor changes taking place in the crust.

About eight-elevenths of the earth's surface is sunken below the rest and covered with salt water.

After the earth has become a cold body, too cold for habitation, it will appear as a bright moon to some other planet.

Geological Formation of the United States—The large fossil remains found in Wyoming and the Black Hills of South Dakota clearly prove that this section first appeared above the sea.

The Gulf of Mexico extended up to the foot of the Rocky Mountains and the Black Hills on the northwest and to the Adirondack and Appalachian Mountains on the east and northeast. The northern shore of this original gulf extended westwardly from the Adirondack Mountains through western New York and Ontario. This period was ages before the formation of the Great Lakes, Niagara Falls and the Niagara River.

As the old gulf receded toward the present gulf, it receded in the form of a large bay, which accounts for the 45 deg. line in the State of Pennsylvania which the oil men of that state so successfully followed in their operations for oil.

The Ozark Mountains were an island thrown up in this large arm of the ocean by the shrinking of the earth's crust. The tendency of this upheaval was to divide the gulf into two smaller arms or elongated bays.

Following the formation of the different rocks, the earth was so hot at the equator that life could not exist and at the poles the temperature corresponded very much to the tropical temperature of the present day. This statement is borne out by the finding of petrified animal remains and tropical plants in the arctic regions. As the earth cooled at the poles it kept driving animal life toward the equator and the time will come when even the equator will be so cold that life cannot exist.

Relative Location of the Large Gas Areas to the Old Gulf—The present Pennsylvania, West Virginia and Ohio gas fields are located on what was the eastern shore of the old gulf. The New York and Ontario fields were located on the northern shore, and the mid-continent field was located on the eastern shore of the peninsula formed by the upheaval of the Ozark Mountains in the center of the old gulf.

Origin of Natural Gas and Oil—The lowest order of animal life came into existence with the formation of the Potsdam and Trenton rocks, and the source or origin of

natural gas and oil must be attributed to the burying and subsequent decay of these mussels and other invertebrates.

During this age there were periods of storm and calm on the globe. When the sea was smooth, the sand was laid down loosely and when it became disturbed the sands were filled with either silicate or lime and cemented together.

In the first case, the spaces between the little pebbles became reservoirs for gas or oil generated by decayed animal life, while in the second case, when the sand was cemented, there was no room for such lodgment for either gas or oil.

Extreme storms during this period laid down what is called the "shell," which was thoroughly cemented, and which held down the gas or oil until the ingenuity of mankind drilled through it.

Oil is a product of natural gas caused by the pressure and confinement of the gases in the rocks, which are laid down like shingles on a roof. There is no such thing as a gas vein but there is a gas reservoir.

Though natural gas has its origin or source in the Potsdam and Trenton rocks, it may have to travel many miles to find an opening into an upper stratum.

Coal and gas or oil have absolutely no connection with each other, as gas and oil were in existence millions of years before the coal measures were laid down. For illustration—the gas of Alden, New York, coming from the Medina sandstone and free from petroleum, is smokeless. If the coal measures ever existed in this locality they would have been a mile and a half in the air.

Shale was originally soft clay.

Rarely can surface indications of either oil or gas be relied upon."

GEOLOGICAL CHART

Archaen—Iron Age Granite, Gneiss, Mica, Schist, Limestone, Crystaline Rock (Without Life)

Cambrian
- Early Lower
- Middle
- Latter or Upper—Potsdam

(Early Trilobites)

Lower Silurian
- Canadian—Calciferous sandstone (N. New York)
- Trenton limestone (New York) The Galena or lead bearing of Illinois and Wisconsin is Upper Trenton, Utica shale, and Hudson shale

Paleozoic (No Birds or Mammals)

Niagara
- Medina
- Clinton
- Niagara shale

Upper Silurian (Fishes, Ground-pine)
- Onandaga (slate, gypsum) Water lime group
- Lower Heidelberg Albany

Latter (Devonian (Fishes))
- Oriskany sandstone
- Corniferous limestone Some places coral reef often contains flint called hornstone
- Hamilton (Flagstone) laminated argillaceous sandstone
- Portage & Chemung—Ferns and flowerless plants

Carbonic (Amphibians) (Coal plants)
- Subcarboniferous
- Carboniferous Coal period
  - Sharks
  - Amphibians
    - Crickets
    - Spiders
    - Flies (May
- Permian—Red sandstone Clayey rocks or marlites (Magnesia limestone) Top of coal measures in Kansas, Pennsylvania and Texas

Era of general submergence Without long eras of verdure or formation of plant beds

Mesozioc Reptilian (Emerging of western half of this continent Mediaeval forms of life Reptiles in Arctic region)
- Triassic
  - Crocodiles
  - Dinosaurs
  - Lizards
- Jurassic (Sierra Nevada Mountains) Mainly red sandstone Palisades
- Cretaceous
  - Grey and green sandstone
  - Shell beds—Rotten limestone
  - Coarse sand-stone and conglomerate
  - (Laramie Mountains)
  - (Wasatch Mountains)
  - Palm, Willow Elm, Maple, Flower
  - Turtles, Sea Saurian, Crocodiles, Horned Dinosaurian, Cormorants and Waders

Cenozoic
- Tertiary
  - Eocene—Hog, Rhinoceros
  - Miocene—Beech, Oak, Poplar, Walnut in Arctic Zone
  - Pliocene—Horse, Stag, Antelope, Sheep
- Quaternary
  - Glacial
  - Champlain
  - Recent


The First Oil Well

VOLCANIC ORIGIN OF NATURAL GAS AND OIL.

By Eugene Coste, E. M., Toronto, Ont.

In the following article on the Volcanic Origin of Natural Gas and Oil, the writer has endeavored to reprint the most essential paragraphs from the paper written by Eugene Coste, E. M., and published by the Canadian Mining Institute. Vol. vi, pp. 73 to 123, 1903.

"Science has long ago recorded and is recording every day in the newly developed oil and gas fields many facts which in my opinion have thrown and continue to throw the clearest light on the origin of the hydrocarbons, whether they be petroleum, natural gas, or solid hydrocarbons.

(A). As everyone knows carbon is the fundamental element of the organic world, but this must not blind us to the fact that carbon is also a very important element of the mineral world. Indeed the predominance of carbon in the organic world is one of the strongest evidences that can possibly be adduced to demonstrate its great importance, during past as well as present ages, in the mineral world (including of course the atmosphere) for vegetables and animals alike had evidently no other source to draw from. When one reflects on all the carbon subtracted from the mineral world during the past geological ages by all the representatives of the organic kingdom, especially since the beginning of the Carboniferous, to form not only the coal beds, but the limestones, he must admit that the primitive atmosphere was very rich in carbon.

Therefore large quantities of this element must have been dissolved in the first fluid of magma of the earth, and large quantities of it must still exist in the fluid magma of to-day under the crust of the earth.

To know and demonstrate in just what form the carbon is there, and how, from it, hydrocarbons were produced are

not essential geological points, and I will consider it quite sufficient to recall that chemists of high standing in the scientific world, such as Berthelot and Mendeljeff, have long ago (in 1866 and 1877 respectively) suggested very probable forms such as carbides under which carbon could exist in the interior fluid magma, and probable re-actions under which hydrocarbon compounds could be generated. The present great daily production of the hydrocarbon acetylene by the simple action of water on carbide of calcium is very suggestive in that respect, and these considerations together with the further one, now proved and admitted, that eruptive magmas are hydato-pyrogenic, namely, contain the more or less notable admixture of water necessary to suggested possible reactions in the formation of hydrocarbons are sufficient in that respect. The vital point is to actually show the carbon and hydrocarbon in the igneous rocks, lavas and emanations proceeding from these internal fluid magmas. That, geology can do and has done, in a great many instances, at points widely distributed over the whole surface of the globe; and, we will now pass in review a few of these instances, namely:

1st. In the Archæan rocks we find carbon under the form of graphite in gneisses, in pegmatite dykes, in granites, gabbros and other rocks, the igneous origin of which is undeniable.

2nd. In the crystals of igneous gneisses and of most granites and other eruptive rocks, gaseous and liquid inclusions are most abundantly found, and these are very often constituted by carbonic acid and hydrocarbons, and also often contain chloride of sodium in solution or in minute crystals.

3rd. Petroleum, or semi-liquid or solid bitumens have often been noticed and cited by many observers as occuring in traps, basalts or other igneous rocks.

4th. Volcanic rocks forming vertical necks and pipes across horizontal strata and containing carbon in the pure form of diamonds are also well known to constitute in South Africa the deposits of these precious stones.

5th. I now come to the hydrocarbons and carbonic acid in volcanic manifestations of to-day. Not later than a few months ago the civilized world was suddenly startled and horrified at the report that an explosion of Mount Pelée had wiped away in a few minutes the entire population of the City of St. Pierre, Martinique Island. From the accounts of the catastrophe then published, it is quite certain that a fearful blast or tornado of gases suddenly shot from the side of the volcano, asphyxiating and burning in a moment 30,000 people. Nothing else, I submit, but gas would carry death so suddenly to so many thousand people, inside and outside of their houses, over a whole city. That these gases were mostly sulphur gases and very inflammable gases (which could be mainly nothing else but hydrocarbons) has also been made quite clear by the accounts of the very few survivors.

We mentioned above that these inflammable gases must have been mainly hydrocarbons (probably mixed with hydrogen and sulphuretted hydrogen), and we draw the above inference from the fact that inflammable or combustible gases thus constituted have often been noticed and observed before in connection with many other volcanic eruptions by scientists of great repute, who were actually able to collect and analyse these gases. For instance; in the Vesuvian eruption in 1855 and 1856, it was observed by Charles Sainte Claire Deville and Leblanc that the lava as it cooled and hardened gave out successively vapors of hydrochloric acid, chlorides and sulphurous acid, then steam, and finally, carbon dioxide and combustible gases.

At Torre del Greco, on the sea shore opposite Vesuvius, during the eruption of this volcano of 1861, Mr. Charles

Saint Claire Deville and Mr. Fouqué gathered and studied the gases from the eruptive lava which was then partly flowing under the sea. The combustible gases from it were collected under water before they could oxidize with the following results, namely:—

	From Fissures of the Lava on Land.		From Fissures of the Lava Under the Sea.			
			10 to 15 metres from land.	40 to 50 metres from land.	Ab't 100 metres from land.	Ab't 200 metres from land.
	Dec. 23	Jan. 1	Jan. 1	Dec. 18	Jan. 1	Jan. 1
Carbonic acid.	96.32	95.95	88.60	59.53	46.78	11.54
Hydrogen and Proto-Carbon	3.68	4.05	11.40	40.47	53.22	88.46

(B). I now pass to my second paragraph in which I propose to show that all the petroleum, natural gas and bituminous fields or deposits cannot be regarded as anything else but the products of solfataric volcanic emanations condensed and held in their passage upward, in the porous tanks of all ages of the crust of the earth from the Archæan rocks to the Quaternary, or in veins, fissures and seams in the case of solid bitumens. Nothing is so simple and therefore nothing so natural as this origin. It can be abundantly proven, and I will divide the data and proofs I propose to adduce for this under the following heads:—

1st. Direct proofs and rock pressure of natural gas.

2nd. Complete analogy of the products of the oil and gas fields with the products of solfataric volcanic action.

3rd. Location of the oil and natural gas fields along faulted and fissured zones, each one presenting a few particularities of its own, similarly to the systems of volcanoes and to the mountain chains of the globe.

4th. The oil, natural gas and bitumens are never indigenous to the strata or formations in which they are found; their "sands" or other deposits are nothing more than natural rock tanks ranging in geology from the Archæan to the Quaternary, and these extraneous products must therefore come from below the Archæan.

5th. Oil, gas and bitumens are stored products, in great abundance in certain localities, while neighboring localities often are entirely barren, exactly as volcanic products would be, and the strata among which they are found are so impervious that it forces one to the conclusion of a source, with powerful energy, directly below their fields.

1st. To the direct proofs given above of solid, liquid and gaseous hydrocarbons in lavas or other igneous rocks, or in emanations clearly volcanic, can be added direct proofs of volcanicity from a few of the oil and gas fields, and these will serve as a link as it were between the volcanoes, on the one hand, and the oil and gas fields where the volcanic origin is not so plainly apparent, on the other.

In the newly discovered oil fields of Texas and Louisiana, and also in the California fields, we have many no less direct evidences of volcanism, though they do not appear to have been understood in their true light. These are, in Louisiana and Texas, the Salt Islands and the "Mounds" of the Coast Prairie, such as the famous Spindletop, near Beaumont, which are clearly nothing else but "suffionis" or "salses," hardly extinct yet, grouped along fractured lines and marking in that region the dying out of volcanicity, that is to say, the dying distant echo of that tremendous volcanic energy which, a little further south, in Mexico, Central America and in the islands and along the south coast of the Caribbean Sea, is to this day so powerfully active.

Abundant proofs of the above statement are to be found in Professor Robert T. Hill's paper, and to me these

proofs are so conclusive that you will pardon me if I again quote copiously:—

"In the generally monotonous monoclinal structure (of the Coast Prairie of the Gulf) there are a few wrinkles or small swells likely to escape the eye of even the trained observer, and yet of a character which may have an important bearing on the oil problem. These are the circular and oval mounds, already described, which were first recognized by Capt. Lucas. When he pointed out Spindletop Hill to me, my eyes could hardly detect it; for it rises by a gradual slope only ten feet above the surrounding prairie plains. I was still more incredulous when he insisted that this mound, only 200 acres in extent, was an uplifted dome. But Capt. Lucas said that I would be convinced of the uplift if I could see Damon's mound in Brazoria County. In August, 1901, I visited that place, and returned for a second look at Spindletop, and was convinced that, if these hills are not recent quaquaversal uplifts no other known hypothesis will explain them. Damon's mound is an elliptical hill, a mile or more in greater diameter, rising 90 feet above the surrounding level. . . . The salt islands of Louisiana were described by Capt. Lucas in the transactions of the American Institute of Mining Engineers before his discovery of oil at Beaumont. (1). These so-called islands, rising from 80 to 250 feet above the surrounding marshes of the Coast Prairie, are hills beneath layers of stratified clay and sand. They belong to the same group of topographic phenomena as Spindletop Hill at Beaumont. By sinking through the superstructure of sand and clay Capt. Lucas located the salt bodies, and determined their horizontal extent, developing also the important fact that, though limited in diameter, they were of great depth, that of Jefferson Island having been penetrated for 2,100 feet without reaching bottom. . . . The bodies of salt discovered beneath the hills of the Coast Prairie are of remarkable size, thickness and purity, notably

those of Louisiana, and one discovered within the past few months at Damon's mound which, for its lower 700 feet, is pure rock salt with occasional traces of oil. . . . It was Capt. Lucas who discovered the relation between the sulphuretted hydrogen fumaroles, gas springs, and sulphur incrustations at the surface and the bodies of subterranean oil; and it was his belief in this association that led him to seek for oil on Spindletop Hill. . . . The oil is closely associated with the mounds, occurring on their slopes or summits. . . . In some localities hot water has been struck below the oil. . . . In the original Lucas well, the oil itself is hot. . . . It had a temperature of over 110° fahr. The oil seems to occur not in any definite continuous stratum but in spots of many strata. Gas in immense quantities and frequently under such pressure as to wreck the wells, has been struck before reaching the oil. This has occurred several times at Spindletop, twice at Sour Lake, and once at Velasco, where the destructive effect was terriffic. Sulphur and sulphuretted hydrogen gas occur in intimate association with the Beaumont oil. In fact, the oil itself is said to contain 1 to 2 per cent. of sulphur, and the fumes of sulphuretted hydrogen are strong in the vicinity of the wells. . . . Underground bodies of sulphur associated with the oil by natural processes have been found in many localities. The Calcasieu section of Hilgard shows at 540 feet in depth solid sulphur rock similar to that encountered at 1,040 in the Beaumont well. At Damon's mound a bed of sulphur from 10 to 40 feet thick was encountered above the salt. Crystals of free sulphur also occur in the cap rock overlaying the Spindletop oil. Capt. Lucas found the sub-strata of the south-eastern part of Belle Isle, above and down to the rock salt, were heavily impregnated with petroleum. Several calcareous strata containing sulphur were also encountered. . . . The wells at Damon's mound encountered small flows of oil at depths of from 400 to 600 feet."

In his last report on petroleum in the Mineral Resources of the United States, Mr. F. H. Oliphant confirms the true nature of these mounds, as here indicated, in this significant remark: "The depth of the wells to the productive bed vary from 880 feet, about the centre of the elevation at Spindletop, to 1,190 feet near the edge of the productive area, indicating that the stratum holding the petroleum is in a general way conical, which condition seems to be verified by the deep wells, less than 500 feet from defined territory, failing to find any trace of the open cellular carbonate of lime and pure sulphur structure encountered on the mounds, at depths of over 2,000 to 2,500 feet. The thickness of the oil-bearing formation is placed by different drillers at from 20 to 75 feet. It is almost pure carbonate of lime with more or less combined sulphur as well as surrounding crystals of pure sulphur."

To the volcanic solfataric phase of phenomena these mounds, or rather as we see, real vertical chimneys, must surely belong. How else could be explained their hot oil, their hot water, and especially their vertical chimney-like masses of sulphur, salt, limestone and dolomite permeated and impregnated with natural gas, oil, and hydrogen sulphuret gas?

If we now transport ourselves from Texas to the Island of Trinidad, at the other end of the circle of oil and asphalt deposits, which, as it has been remarked, border the Gulf of Mexico and the Caribbean Sea, what do we find there? According to Clifford Richardson and to Edward W. Parker, of the United States Geological Survey, "the chief source of the supply (of asphaltum) is a lake of pitch filling the crater of an extinct volcano. This lake lies 138 feet above the sea level, and has an area of 114 acres. The supply is being partially renewed by a constant flow of soft pitch into the centre of the lake from a subterranean source." The solfataric volcanic emanations at Trinidad are also abundantly

attested by the many mineral springs on that Island, by the strong thermal waters with borates, iodides and sulphur compounds intimately mixed as an emulsion with the bitumen of the pitch lake, by the gas issuing from the cracks in the bitumen, and by the indurated clays, burnt red shales and porcelanites to the southward of the lake.

Similarly, in California, through all the extensive oil fields of that country situated along the coast Range which has been only recently uplifted, the solfataric volcanic phenomena are most abundant to this day in connection with the oil deposits which are found in very disturbed and dislocated strata of the Cretaceous, Tertiary and Quaternary. Here, the shales, interstratified with the bituminous and oil sands, have become reddened and burnt or bleached to white shales, and changed to porcelanites by the solfataric vapors, and they have also been greatly calcified and salicified by the hot calcareous and silicious waters. Hot natural gas and hot sulphuretted hydrogen emanations, as well as hot and boiling waters, issue yet from the hot ground in a number of places as at the Calera Rancho, six miles west of Santa Barbara, where, on the ocean shore, an area of twenty acres has lately subsided some 25 feet, and from the hot ground of which heavy petroleum oil oozes out with sulphurous and other vapors and hot saline waters. Mr. A. S. Cooper, State Mineralogist of California, in a paper on "The Genesis of Petroleum and Asphaltum," devotes a great deal of space to these red burnt and white bleached shales as connected with the genesis of bitumen in California, but he attributes the evidences of heat and heated vapors and steam everywhere shown by them to chemical heat engendered in the shales themselves in some mysterious way, or generated in some even more mysterious way in the metamorphic rocks below the Cretaceous.

This "chemical heat," according to Mr. Cooper, distills the carbonaceous vegetable matter in the rocks and the

resultant gas, oil and asphalt migrate upward into the Cretaceous, Tertiary and Quaternary rocks to fill there the gas and oil sands and to form the asphalt veins.

But why this "chemical heat" should have been so accommodating as to have waited until the Tertiary and Quaternary formations were deposited before metamorphosing and distilling the lower formations is not clearly explained.

There remains now one more direct proof of volcanicity in the oil and gas fields to which I desire to especially draw your attention. This proof is general and present in all the oil and gas fields, and therefore of primary importance in a consideration of the origin of oil and gas; I refer to what has been called the rock pressure of natural gas. This great force, which often has thrown out of a well high above the derrick an entire string of tools weighing thousands of pounds and which often gushes the oil and the pebbles of the oil sands with terrific force hundreds of feet high in the air cannot be explained in any other way than as a remnant or spark of the initial volcanic energy, the stupendous force of which in volcanoes has so often caused most tremendous explosions, appalling in their magnitude and effects, blowing out enormous craters and sometimes whirling out without warning, as from the mouth of a mammoth cannon, a destructive tornado of inflammable and irrespirable gases over a whole city, as in the recent memorable instance of St. Pierre, Martinique. In some of the oil and gas wells this pressure of the gas has registered as high as 1,525 lb. to the square inch, or over 100 ton to the square foot, but it is generally considerably less and ranges ordinarily between 200 lb. and 1,000 lb. in fresh fields when first struck, at depths of from 500 to 3,000 feet. It varies greatly in the different fields from wells of the same absolute depth, even though the two fields are not far distant, as for instance in the case cited by the late Professor Edward Orton, where a

well in Oswego County, New York, only gave a pressure of 340 lb. to the square inch from a depth of 2,100 feet, at which the gas was struck in the Potsdam sandstone, while another well in Onondaga County, N. Y., the "Munroe" well, where the gas was struck in the Trenton limestone at 2,370 feet, gave a pressure of 1,525 lb. to the square inch. But, and this is a very significant fact, which indicates plainly the internal origin from below, in the same field when gas is found in different strata, as it very often is, the strongest pressure is always in the lower stratum, and the rate of decrease of that pressure from the lowest stratum to the upper ones is very irregular, evidently depending on the more or less open channels of communication between these strata which existed at the time of the solfataric volcanic activity under that field, channels which have now long ago been closed up as a rule. The other significant fact of the rock pressure of natural gas is that it is a continually decreasing pressure from the time the gas is first used in a new field until finally it is all exhausted. This shows, without a doubt, that there is nothing now behind that pressure, no hydrostatic column or anything else; the gas possesses this energy, *per se*, it is its own life, and it imparts it to the water, or to the oil sharing the sands with itself to make them flow violently at first, but before long this decreasing pressure becomes powerless and the oil has to be pumped. This would not be the case if a constant hydrostatic head was behind it; therefore, this fact alone is enough to condemn absolutely Professor Orton's and Professor White's theory of hydrostatic or artesian water pressure as an explanation of the rock pressure of natural gas. Paleozoic oil and gas rocks of North America are far from being porous enough to form permeable sheets arranged in basin form between impervious layers and with porous outcrops, and thus never fulfill all the conditions necessary to constitute artesian basins. These rocks, ranging in geology from the Potsdam all the way to

the Pittsburgh sandstone, just above the Pittsburgh coal, have in many cases furnished oil and gas sands forming in shale series irregular bodies, unconnected and without outcrop. In this case, how can any one seriously adduce an artesian water pressure to account for the rock pressure of the gas? But, even in the case of the Trenton limestone, which is a thick continuous stratum with long outcrops to the north, and forming a basin under Ontario, it is far from being pervious enough and therefore some of the conditions for an artesian basin are not there, as absolutely proven by a number of wells which were drilled right through the whole series down to the Archæan below, and never found any water. Even at Collingwood, where the Trenton limestone outcrops under the town and under the Georgian Bay, a number of wells, drilled there, have found only sulphurous and saline waters in small quantities below 130 feet; and, three wells which were drilled under the mountain, fifteen miles south of Collingwood, pierced the whole Trenton limestone, from 1,160 to 1,750 feet, without finding a drop of water in it, though the top of the Trenton in these wells, situated miles one from the other, was about 275 feet below the level of the Georgian Bay in each instance. Where is Professor Orton's artesian water column here? Wanting absolutely, right where it should be on the track between Ohio and the outcrops of the Trenton. It is only fair to add here that Professor Orton himself, in his presidential address read before the Geological Society of America, December 28th, 1897, abandoned as untenable his theory of artesian water pressure as the source of the natural gas rock pressure. Yet, there is surely a cause for these great pressures going up sometimes as high as 100 atmospheres, recorded by natural gas. If it is not a volcanic energy, what is it? Svante Arhenius, the distinguished Swedish physicist, has figured out that the crust of the earth is solid down to about twenty-five miles, and that at this depth, where the temperature

must be 1200° C. and the pressure about 10,840 atmospheres, commences the fluid magma; also that, at the depth of about 186 miles, the temperature must without doubt exceed the critical temperature of all known substances, when therefore the liquid magma must pass to a gaseous magma subject to extremely high pressures. Here then, only twenty-five miles, at most, below the gas fields, is an adequate source for the natural gas pressures, and this is the only adequate source we can possibly find. We also know that light hydrocarbon or natural gas is emanated abundantly in all the volcanic regions from these interior masses. We therefore have there, below the crust and there alone, the source of both the natural gas and of its strong energy and life, called rock pressure.

2nd. Complete analogy of the products of the oil and gas fields with the products of the solfataric volcanic action.

It is well known, and our brief review in the first paragraph of this paper shows, that the great solfataric volcanic products are water, chloride salts, sulphur, sulphuretted hydrogen, carbonic acid and hydrocarbons with often an admixture of hydrogen, oxygen and nitrogen. That all oil and gas fields in every part of the world present the above products in a remarkably constant association, though of course, occasionally a few of them may be missing, is a fact so well known that it is unnecessary for us to do more than refer to it briefly. We have already seen, that in the case of the Texas and Louisiana fields this association, mainly, of salt, sulphuretted hydrogen, sulphur, and hydrocarbons is most pronounced. So it is clearly in the Lima oil fields, including the Canadian fields, and in the California fields.

But, even in the Appalachian fields of New York, Pennsylvania and West Virginia, where the oil is free from sulphur and the gas is generally free from sulphuretted hydrogen, yet it is not always so and sulphur waters are very often found in the wells of that region almost as generally

as salt waters and constantly associated with the oil and gas. The occasional presence of sulphur in the oil and gas at a few places along the Appalachian belt, especially in New York State, where it is found in lower formations, confirms Dr. David T. Day's suggestion that, if as a rule the Pennsylvania oil and the Lima oil differ in their sulphur contents and color, it is probably due to a filtering process which the Pennsylvania oil has been able to undergo in its passage upward through Devonian and Carboniferous fine-grained shales and sandstones.

3rd. Location of the oil—and gas—fields, and of the solid bitumens along faulted fissured zones, similarly to the system of volcanoes, and to the mountain chains of the globe.

Few geologists are to be found to-day who do not admit at least a liquid sub-stratum under a solid crust for the constitution of our planet, be the centre of it gaseous, liquid or solid; and who do not also recognize the cooling and shrinking of this interior fluid mass as the grand cause of volcanicity including not only all the direct volcanic phenomena but also all the dislocations, movements, faulting and fissuring of the crust of the earth, except possibly some local and minor displacements. The mountain chains, therefore, and the volcanoes stand out as the chief results of one profound cause in which the entire central mass of the whole sphere is in operation. It is only natural then to find the mountain chains and volcanoes of the earth in such long straight lines marking the much faulted and fractured grand circle zones of least resistance of that sphere. But, in the resulting effects, on the earth's crust, of the pressures causing these great orogenic and volcanic dislocations, we must expect to find all degrees of intensity from the immense parallel folding, fracturing and faulting, so grandly illustrated in so many of the great systems of mountain chains, to numerous zones much less dislocated and fractured, generally parallel to the neighboring mountain range or to some

main offshoot of it, and in some cases possibly hundreds of miles away from it, and marking the progressively dying out efforts and effects of that particular great orogenic revolution from the mountain chain outward. These minor fissured and fractured zones may be of such slight disturbances and fracturing that this fact may hardly appear, especially when the surface is largely drift covered. Yet, the pent-up gases and vapors of the interior may during the active period or periods of these disturbances have succeeded in forcing their way up along these zones to or near the surface. Even in North America, where so much deep drilling for oil and gas has so long ago taken place, several of these disturbed and fractured zones have only been indicated in the last few years in the drilling operations connected with new discoveries of oil and gas. Such was the case in the North Western Ohio gas and oil fields as shown by the late Professor Edward Orton in these words: "Up to a recent date it was not known that the underlying rocks failed to share the monotony of the surface, but the explorations of the last two years have revealed the surprising fact that the rocky floor of the Black Swamp of old time is characterized by far greater irregularity of structure and by far greater suddenness and steepness of dip than the strata of any other portion of Ohio. The entire floor of North Western Ohio, including the lake counties, as far east as Lorain County, is seen to lie in a disturbed and uneasy condition. . . . The Findlay break is abrupt and well marked, and is indeed the most remarkable fact in the structural geology of Northern Ohio. The occurrence of petroleum and gas, but especially of the latter, in North Western Ohio has been found to be associated with greater irregularities of structure than are known elsewhere in the State, except in a single locality. It is in Findlay that the most marked disturbance occurs, and the great supplies of gas that are found there appear to be closely connected with this disturbance."

Mr. Robt. T. Hill in his paper on the Beaumont oil fields, previously referred to, says! "There is some evidence that the Coast Prairie overlap conceals a line of serious deformation, which may be a sharp fold, with an increased dip coastward, or a zone of faulting." Concerning this same region, Mr. E. T. Dumble says: "While the Coastal Plain is now just what its name implies, during Tertiary times, it was subjected to oscillations, accompanied by certain phenomena which marked the dying out of vulcanism in this region."

In the theory, which he formulates to explain "the oil phenomena" of the Texas mounds, Mr. Hill suggests that artesian saline waters bring up the sulphur and oil along this indicated line of faulting in that region; I simply go a little further and claim that this line of faulting gave access to volcanic emanations bringing the water, salt, sulphur, oil and gas from the interior in the state of vapors and gases, which condensed more or less near the surface, some escaping yet in their gaseous state as the hydrogen sulphuret and the natural gas.

In the famous Appalachian oil and gas belt bordering and following the Appalachian Mountains from the eastern shore of Lake Ontario to Alabama, for the distance of 900 miles, the evidences of parallel folding, faulting and fracturing are most numerous, as shown in the reports and maps of the Pennsylvania, Ohio and West Virginia Surveys, and if so many anticlines, slopes, synclines and terraces have proven to be good oil and gas fields all through this vast extent of country, and from rocks ranging from the Potsdam sandstone to the Upper Productive Coal Measures, it is certainly not because these hydrocarbons have moved sideways to the anticlines (as we will see below they cannot do on account of the imperviousness of the strata) but because this region being, at certain geological periods, a dislocated and fractured zone, the hydrocarbons have then moved

upward from below through these faults and fissures. This is plainly evidenced by the solid vertical core of hydrocarbon at the Ritchie Mine, Ritchie County, West Virginia, where a straight vertical fissure, 4 feet wide in the sandstone, but much smaller and more irregular in the shales, is completely filled with a mineral pitch or inspissated petroleum, called Grahamite by Wurtz, and first described by Professor Leslie in 1863, and lately fully reported on by George H. Eldridge, of the United States Geological Survey, who seems to admit, with Professor White, of the West Virginia Geological Survey, that the source of the Grahamite is the oil in the Cairo sand 1,300 feet down, but, that does not explain the source of the oil in the Cairo sand which, we will see, can be traced to below the Archæan. Therefore, the Ritchie Mine Grahamite vein, though only badly defined when traversing the shales, must, nevertheless, have extended at one time to below the Archæan.

4th. That gas, oil and bitumen are never indigenous to the strata in which they are found and are clearly secondary products is abundantly proven by the study of the different petroleum districts all over the world where the deposits are seen to form most irregular patches, pools and fields of porous rocks of all ages impregnated with the petroleums. Any porous reservoir of the entire sequence of the sedimentary formations, from the Quaternary down to the crystalline rocks may be filled with the petroleums and even fissures in the crystalline rocks below all the sediments (near Newhall, Los Angeles County, California,) are thus found filled with a very light oil, almost naphtha. In many of the fields the oil and gas are obtained in a number of different sands or reservoirs some of which are hundreds and thousands of feet lower than the upper one and in neighboring wells the oil and gas are often tapped at entirely different depths. All of which plainly demonstrate that the source of the petroleums is below the crystalline rocks.

5th. Another and last proof which I want to adduce is that the petroleum and natural gas deposits are such locally separated and accidental accumulations, often in such very large quantities, that their source must be from the deep-seated volcanic reservoir directly beneath, which, alone, is abundant enough and was powerful enough to force such large quantities of hydrocarbons through most impervious strata during periods of volcanic activity under these fields.

In discussing the origin of petroleum and natural gas, the mistake has often been made to suppose and admit that certain "horizons," especially of shales, are entirely "bituminous" over very large areas and are to be found spreading out uninterrupted, like coal beds for instance, over wide regions. In fact, in most of the papers which I have read discussing this subject, some more or less extensive bituminous shale horizon, sometimes situated above strangely enough, is always pointed at as the source of the oil; but, that, of course, as I have already remarked, does not solve the question of origin—it only defers it and shirks it as it were. But furthermore, I submit, that the evidence to be gathered in all the oil and gas fields show how localized and accidental the deposits of these products are and that in no case do they form widely and uniformly spread "sheets." Carbonaceous shales sometimes form such "sheets" but not bituminous shales. Hunt has long ago denied that the so-called bituminous shales "except in rare instances contain any petroleum or other form of bitumens." These two words "carbonaceous" and "bituminous" are very far from being synonymous, and this fact has too often been lost sight of. But even when shales are really bituminous (that is contain hydrocarbons) they contain these only in spots, as well illustrated in the oil-shale fields of Scotland, where, in the different quarries, different beds of shales occupying a series under the coal 3,000 feet thick, are worked, the same

bed not being found rich or "impregnated with oil" in more than one locality or two.

We have seen above how well the mounds and salt islands of Texas and Louisiana illustrate this localization of oil and gas deposits in a few small spots, here and there, with extensive barren stretches of the same formations between; and that the abundance of the oil obtained from under little Spindletop at Beaumont is so remarkable that it entirely precludes the admission of an indigenous source from the sedimentary strata under or near this mound.

All other fields show the same spotted and local feature of impregnation in their petroleum deposits. Even in North Western Ohio and Indiana where the oil and gas stratum is a limestone and where, therefore, solfataric waters could partially dissolve and dolomitize this limestone, thus rendering it more porous and spreading the subsequent oil and gas deposits more than usual, yet even there the 300 million barrels of oil and the enormous quantities of gas, which have been obtained in the last 18 years, have been produced from very limited areas in these States, though in many other counties of these and adjoining States the same fossiliferous stratum, viz., the Trenton limestone, has proven barren of hydrocarbons notwithstanding that the organic source (if such there was) would be available there just the same as in the neighboring oil fields, as well as many anticlinal domes and other varieties of flat structure which have been regarded as necessary and sufficient to the accumulations of oil and gas travelling through from fossil sources.

The Berea grit in Ohio affords another most striking example of the localization of oil and gas pools. Notwithstanding that it underlies most uniformly 50 counties of Ohio and 20,000 square miles and that it overlies the greatest shale formation of the entire State, viz., the Ohio shales, ranging in thickness from 300 to 2,000 feet, and that it is covered by some 400 feet of impervious shales, viz., the

Berea and Cuyahoga shales, yet it is only productive of oil and gas at a few points. How is it that since, as Professor Orton said, "There is everywhere underlying the Berea grit an abundant source of oil" (the shales) and that, since the impervious cover is mostly always there over this vast territory protecting a good continuous, often porous, sandstone reservoir, that in point of fact, as Professor Orton also said: "There are but very few localities in these 20,000 square miles where any noteworthy value has thus far been obtained from the formation in the line of these coveted supplies, and but a single field of large production"? A few more fields have been found in the Berea grit since the above was written, such as Corning, Scio and others, but yet, after very considerable drilling, not one per cent. of the 20,000 square miles has been found productive; and, where it has been, as remarked also by Orton in the same report, an "abnormal structure or dislocation of the strata" was noticed, like at Macksburg. This indicates the fracturing of the strata necessary for the local impregnation of the Berea grit and other "sands" with oil and gas.

But where the localization of oil is most striking is in the famous oil field of the volcanic peninsula of Apscheron, near Bakou, Russia, where from a small area of not over eight square miles a production of oil of over 900 million barrels has now been obtained.

The very local and accidental distribution of the oil and gas fields is very unlike what would be expected from deposits of organic origin, which like the coal beds would naturally spread out uninterrupted over wide regions. On the other hand, volcanic products are "*a priori*" found localized along the lines of volcanic activity and there in large quantities, while the neighboring localities or districts not subjected to this volcanic action are barren. If we now recall the well known geological fact that volcanic activity is, and has been during all geological ages, shifting and in-

termittent along the fractured zones of the earth crust, that is to say that, while it manifested itself intermittently in a certain region during a certain period, in subsequent ages it died out and became entirely quiescent in that particular region to break out anew in other portions of the earth, then we will realize that natural gas and oil, though volcanic products, are to-day in most every field where they are found, stored products not now renewing themselves in the recesses of the earth. We will also thus understand why the rock pressure and quantity gradually decrease as we take these products out of their deposits, the volcanic activity which brought them there, through faults and fissures, was active, as it always is, only for a time, and now that this activity has expired these faults and fissures have closed up and the volcanic force is unable to refill the reservoirs, just as it is in most mining regions of the earth where a similar volcanic energy was, at one time, the immediate cause of the filling of fissures, veins and lodes now long ago solidified with quartz and other vein-stones more or less mineralized.

(C). Complete inadequacy of all organic theories of origin.

I have shown that volcanic emanations of hydrocarbons are a natural geological process of to-day, abundantly verified and witnessed in actual operation in volcanic eruptions and phenomena all over the world.

Can as much be said of any of the organic theories generally advanced to explain the origin of the hydrocarbons? Evidently not! None of the processes called on by these organic theories are to be witnessed in operation anywhere in nature to-day. The late Professor Edward Orton, a profound believer in and a strong defender of the organic origin of petroleum, acknowledged this point plainly when he said in his presidential address before the Geological Society of America: "It is easy to see how the bituminous series may result from the destructive distillation of either

vegetable or animal substances enclosed in the rocks, and wherever conditions can be shown that provide for such distillation we are not obliged to go further in our search. Destructive distillation can take effect in organic matter that has attained a permanent or stable condition in the rocks, like the carbonaceous matter of black shales or coal; but it seems improbable on many and obvious grounds that this can be the normal and orderly process of petroleum production. This production of petroleum must be in active operation in the world to-day; at least it seems highly improbable that a process coeval with the kingdoms of life, growing with their growth and strengthening with their strength, a process that was certainly in its highest activity throughout Tertiary time, leaving a most important record in the rocks of that age, should suddenly and completely disappear from the scene upon which it had wrought so long and upon which all other conditions appear to be substantially unchanged." We have seen above how far from having disappeared from the scene is the volcanic process of petroleum production, but Professor Orton was only looking to find in nature a petroleum production process "coeval with the kingdoms of life," and that he could not find it simply because it does not and never did exist. To me this is most clearly proven by the simple consideration of the natural geological processes of decomposition of organic remains and of the conditions pertaining in the oil and gas fields.

First. It is quite certain that the decomposition of animal bodies, as taking place in nature to-day, and we may, no doubt, say during all ages, is so rapid that the decay or combustion is complete before the entombment in the sedimentary rocks of these animal bodies, preserved in any way, can possibly take place. This is no doubt why instances are so rarely cited in geology of partially decomposed and preserved remains of animal bodies being found; only most exceptional cases, such as a few remains preserved in the

antiseptic waters of peat bogs or a few frozen remains of Elephas, are given; but these exceptions only confirm the rule which is, viz., when there is anything left at all it is the shell or bones or their moulds or casts and no trace of the body is to be found. The fact that a few shells are sometimes found full of petroleum is a conclusive proof that this oil is a subsequent infiltration into the shell, as in the case of silt, silica, pyrites, calcite and many other minerals filling shells, a modicum of oil is all each shell would contain if the petroleum originated from the body, and invariably, when petroleum is found in fossil shells, it is also found in the porous or seamed strata in which the shells are embedded, showing the infiltration and impregnation from without.

Second. It is also equally certain that there is only but one normal process of decomposition and preservation of vegetable organic matter in nature to-day and in ages past, and that is the decomposition of it into carbonaceous matter, viz., peat, lignite and coal. This process is in active operation in the world to-day, as it has always been, and it is the only normal process "coeval with the kingdoms of life" that geology teaches us. Not one single authentic instance can be adduced, from the actual normal processes of nature, of any decomposition of organic matter "primarily" into petroleum. How could it be? The same conditions of low temperatures and of all other factors entering in the normal decomposition of vegetable remains must give only the one result and cannot possibly give two different ones, especially in the same strata and at the same places, for oil sands and coal beds are often contiguous. If then we do not find carbonaceous matter in any quantity below the carboniferous period, as the A B C of geology teaches us that we do not, the simple reason of it is, as long ago admitted by geologists, that, before that period, the favorable conditions for vegetable growth had not yet developed to any extent, and not that it was transformed into petroleum, as attested

by the small quantity of carbonaceous matter found in the Devonian and Silurian strata, which are witness and proof that the one normal process of decomposition of vegetable matter into coal was then already going on.

Then, since animal organisms were never entombed in the rocks, and since vegetable life was quite insufficient before the Carboniferous Age, how can the organic theories of origin be adduced to explain all the oil and gas found below the Carboniferous, and that means all the enormous quantities of oil and gas of the Lower Silurian limestone of Ohio and Indiana, and it also means almost all of the very large quantities of oil and gas developed in the last 40 years along the Appalachian belt which has been found under the coal in the lower and Sub-Carboniferous and in the Devonian and Silurian; and, much more in other fields. The fact often cited by the numerous exponents of the organic theories, as in the above quotation of the late Professor Edward Orton, that, by destructive distillation, petroleum and gas can be obtained from coal or carbonaceous matter, and also from fish oil, lard oil or linseed oil, etc., will not serve here at all, for not only there was too little to distill in the rocks prior to the Carboniferous, but, what little there was, was not distilled and is to be found there to-day, undistilled, as the Paleozoic oil rocks of the oil regions of North America have, without the shadow of a doubt, remained unaffected by metamorphic agencies, and have never been subjected to the heat necessary to effect this distillation of organic matter. Nor have the rocks of the Texas section, and yet we have seen that petroleum, gas and asphalt are found in them from the Ordovician to the Quaternary. This destructive distillation of carbonaceous matter (and, we repeat, there is no other organic matter entombed in the sedimentary rocks but carbonaceous matter) could not possibly take place without leaving a residue of coke and of ash, and not only these residues have never been found under the oil and gas fields,

but we know for certain that they do not exist.

In fact, if this distillation had taken place, there would be no coal fields anywhere as they would all have been changed into coke-beds.

We see, therefore, to what absurd deductions we are led by the organic theories of the origin of petroleum, viz., 1st, Abundance of vegetable life before the Carboniferous; 2nd, No coal anywhere on the globe."

Early Geological History of Western New York and Ontario (Frank Westcott.)—"At one period during the earth's transformation, following the recession of the original Gulf of Mexico in a southwesterly direction from New York and Ontario, what is now Lake Ontario and Lake Erie was one large body of water, with the St. Lawrence as an outlet and no Niagara Falls. This geographical condition was caused by the slowly receding gulf.

The Susquehanna River, which runs south through Pennsylvania, ran north through Seneca Lake—if Seneca Lake existed at that time—and emptied into what is now Lake Ontario.

Partial proof of this is that about ten miles north of Geneva, New York, the drill penetrated three hundred feet of soil before striking rock, showing the bottom of an extinct stream.

The Niagara river was forty miles wide, as is shown at the present time by the hills back from the river on both sides. As the water receded through the St. Lawrence Valley, Niagara Falls was formed and the larger share of the water of Lake Erie drawn off. Lake Erie, as is well known, is a very shallow lake. Niagara Falls has been cutting back toward Lake Erie at the rate of eighteen inches to two feet per year ever since its formation. The time will come when there will be no Lake Erie, but a river where Lake Erie now is.

All the lakes in the State of New York with one exception are glacial lakes, and run north and south, being extremely deep at their southern extremity. Oneida Lake, the only exception, is a very shallow lake, twenty-two miles long and five miles wide. It was caused by the squeezing up of the Adirondack Mountains, which were not of volcanic origin. Oneida Lake lies in a synclinal and its bottom is the Trenton rock.

Lake Ontario, which averages eight hundred feet deep rests on the Trenton rock, and the southern shore, in ages gone by, was about thirty-five miles south of its present shore.

From Oneida, New York, to the Atlantic Coast there is no chance to obtain either gas or oil, as the lower rocks are on the surface.

Origin of Names Applied to New York State Formations—The Trenton rock receives its name from Trenton Falls, New York, where it outcrops. The Clinton takes its name from Clinton, New York; the Medina from Medina, New York, and the Niagara from Niagara Falls, New York.

These formations dip to the south and come up to the mountains of Tennessee and Kentucky."

GEOLOGY OF THE MID-CONTINENTAL OIL AND GAS FIELD

By Erasmus Haworth, State Geologist, State Geological Survey of Kansas.

A. Geography—"The term "Mid-Continental Oil and Gas Field" was first applied to the oil and gas fields of Kansas and Oklahoma. For a number of years this was all the territory covered by the name. Later, through the influence of the United States Geological Survey, the name was extended so as to include the oil fields of northern Texas around Electra and Corsicana, and the oil and gas fields of northwestern Louisiana.

In Kansas the field covers a zone extending from around Kansas City southwestward across the State. Its western limit has not yet been determined, but on the south it is known to reach westward to beyond Arkansas City. The extreme southeast corner of Kansas and northeast part of Oklahoma are out of the oil zone. In Oklahoma the zone widens and reaches west to Healdton, a few miles west of Ardmore. From here it crosses into Texas around Wichita Falls and Electra. Possibly the Healdton, Wichita Falls, and Corsicana fields are distinct from the main field and from each other, but probably not. The oil fields in the northeastern part of Louisiana also seem to be distinct from the others, but geographically may be included.

B. Geology—Throughout the greater part of Kansas and Oklahoma the oil and gas bearing formations are the Pennsylvanian series of the Carboniferous system. In the western part of the field, however, the surface rocks are Permian, as around Augusta, Arkansas City, and Healdton. The Permian here is not very thick and the wells pass through it down into the Pennsylvanian, unless it should be at Healdton, where the geology has not been very well worked out. Also, in the Wichita Falls area the surface rocks are of Permian geologic age, but the wells, doubtless, reach downwards into the Pennsylvanian. At Corsicana the surface is covered with cretaceous rocks, which seem to be the oil producers, and in northwest Louisiana from cretaceous or younger rocks.

For convenience of discussion it may be well to begin with the lowermost Pennsylvanian rocks and consider them in order upwards. For this purpose the geological section of Kansas will be used mainly, because it has been worked out here better than elsewhere. Conditions in Oklahoma different from those in Kansas may be explained later.

The Mississippian Floor—For convenience of studying the mass of stratified rocks which are important in connection

with oil and gas production in the mid-continental field, we may start with the Mississippian limestone formation and look upon it as a floor upon which all other rock masses rest. These Mississippian rocks or limestones cover the surface throughout a large area in northwestern Arkansas, northeastern Oklahoma and southwestern Missouri, cutting off a little corner in the extreme southeast part of Kansas. The accompanying map shows the areas where the Mississippian limestones are exposed to the surface.

The upper surface of the Mississippian dips westward at a gentle slant throughout this entire region, but the exact amount of dipping differs quite materially in different places. Along the south line of Kansas it has been found by well borings that it dips west almost exactly twenty-five feet to the mile on an average. Southward, in Oklahoma this dip increases to from 40 to 75, and even to 100 feet to the mile in extreme instances, and the direction of maximum dip gradually bears more to the southwest.

The top surface of the Mississippian, however, lacks a great deal of being regular, having been made irregular by surface erosion, that produced river channels and river valleys in the top of the limestone which often throw our calculations into error from 50 to 100 feet. Still further, the rate of dip is quite uneven, although for a long stretch it is almost uniform. Locally, we have waves produced at intervals, so that here is a ridge and there a valley, etc., making slight differences of depth at which the limestone may be reached.

How far to the west the Mississippian extends no one knows to a certainty, nor do we know but that the formations may change their principal properties so they would be difficult to recognize. It is probable, however, that no such changes amount to much within the distance as far west as Ponca City.

Cherokee Shales—Immediately above the Mississippian limestone lies a mass of shales, which, in eastern Kansas is about 450 feet in thickness, but which thicken greatly to the southward and westward. In the vicinity of Sedan, in Chautauqua County, they are about 600 feet thick, and south in Oklahoma in the vicinity of Drumright they are still thicker. Dr. Carl D. Smith*, of the U. S. Geological Survey, calls them about 1000 feet thick at the Glenn pool. Therefore, they are wedge-shaped, growing thicker to the southwest and thinner to the northeast.

Sands in the Cherokee Shales—The Cherokee shales have within them many sandstone beds which are the richest and greatest producers of oil and gas in the entire territory under consideration.

Near their top, in the vicinity of Peru, Kansas, is a well developed sandrock, 50 feet or more in thickness, which is very productive of oil and gas, and which has been named the "Peru Sand," probably identical with the Skinner sand. It is doubtful about this sand extending continuously in any direction very far, but rather within a few miles it will pinch out and later come in again. That characteristic seems to be true of practically all the sands in this part of the country.

Below the Peru sand lies the main producing sand at Bartlesville, named the "Bartlesville Sand," which lies in Kansas about 200 feet below the top of the Cherokee shales, but in the Cushing field is about 300 feet below the Peru sand. It is about 100 feet thick and is very productive. It is the producing sand in all the best wells in Kansas and in the vicinity of Bartlesville, Collinsville and on down south to the Glenn pool, and in Cleveland and Drumright, where wells have a capacity of from 5000 to 8000 barrels per day and a depth of 2500 to 2800 feet, as explained for the Peru sand.

*Smith, Dr. Carl D., U. S. Geol. Sur. Bul., 541, Fig. 1, pp. 42.

Other sands have been found which occupy position below the Bartlesville sand, the most important of which has been named the "Tucker Sands" and lies near the base of the Cherokee shales. In some other localities still other names have been given, but in general it may be said that there is some little doubt regarding the reliability of names of sands that have been used for wells from 25 to 100 miles apart.

Fort Scott Limestones—On top of the Cherokee shales lies the Fort Scott limestones, which, in earlier days, were named the Oswego limestones, a term by which they are still known to many of the drillers. These limestones in reality are two in number, separated by a shale bed from 6 to 15 or 20 feet in thickness. The lower limestone at Fort Scott is the Fort Scott cement rock, and covers the surface throughout the main part of the town. Above this is the upper Fort Scott limestone which does not have the cement quality. Drillers here and there throughout the oil field usually do not separate these two from each other, and as they vary in thickness from place to place sometimes they are reported as over 60 feet in thickness. However, one should understand that, in many places, two of them exist separated by a shale bed of from 6 to 20 feet, as above stated.

This limestone mass is interesting in a good many ways. First, when the driller reaches it he knows he may be close to a productive sand, and proper care should be given. Next, it is not at all unusual for a considerable amount of oil or gas to be found within the limestone, so that one should not be surprised at such an occurrence. The so-called Wheeler sand, according to Buttram,* is, in reality, the Fort Scott limestone. At Drumright it is 75 feet thick, and lies about 2100 feet below the surface.

Pleasanton Shale—Above the Fort Scott limestones we have a series of alternating beds of limestones and shale with

*Buttram, Frank, Oklahoma Geol. Sur. Bul. 18, p. 41.

many sandstones occupying a part of the shale. These are of relatively little importance, although here and there the sandstones develop into reasonably good oil producers. The first heavy shale bed which is reached above the Fort Scott limestone in Kansas is known as the "Pleasanton Shale" on account of the wide outcropping in the vicinity of Pleasanton, Kansas. In many places these shales are almost all changed into sandstone, while elsewhere they are typical shales. Farther to the west and southward they carry sandstones which are important producers. In Oklahoma, particularly, and also in Kansas to a lesser degree, sandstones which seem to lie in the equivalent of the Pleasanton shale become very productive, particularly in the Cushing field.

Bethany Limestone Series—Above the Pleasanton shales, and resting comfortably upon them, we have another series of alternating limestones and shales. Each individual limestone has been named and also each shale, but for our purpose we will speak of the entire mass as the Bethany Limestone System. In Kansas this entire mass is about 300 feet thick and will average about 65 to 75 per cent. limestone for the entire 300 feet. In most of the well records reported, the entire distance is reported as limestone, although occasionally otherwise. In Oklahoma this group of limestone frequently is called the "Big Lime," because the shale beds in places become very thin and the limestones thicker, so that the driller neglects the shales.

Iola Limestones—Above the limestones just described and resting comfortably upon overlying shales we find a very heavy limestone which has a great extent in Kansas, but which does not retain its thickness into Oklahoma. This is the Iola limestone, and is a very important marker in drilling in Kansas. At Iola it is about 40 feet thick, and occupies the surface of the ground immediately under the town of Iola.

Lane Shales—Above the Iola limestone is a heavy mass of shales which have been named the Lane shales, and which in places carry heavy beds of sandstone that may become producers of oil and gas at any place throughout the mid-continental field. The Lane shales average 100 feet or more and in some places reach fully 200 feet. It is quite possible that the sands within the Lane shales are the Lawton sands of Oklahoma. They lie above the Wheeler (Fort Scott) sands about 700 to 800 feet.

Allen and Stanton Limestones—Above the Lane shales we have two limestones, well marked in places, which are separated from each other by the Vilas shale beds of variable thickness but usually from 20 to 50 feet. The lower one of these is known as the Allen limestones on account of its occurence in Allen County, Kansas, and the upper one is called the Stanton limestone, an old name given it by Professor Swallow in 1866. These two limestones usually are counted as one by well drillers, because in most cases the Vilas shale bed between them is so small that the well drillers do not recognize it. The two jointly constitute a very heavy mass of limestone which covers the surface throughout large areas of Kansas and, hence, are worthy of special recognition. The sandstones within the Lane shales below have already been mentioned, so that when a well driller finds he is passing through the Allen and Stanton limestone he may not be surprised to find a good flow of gas or oil in the next sandstone.

Lawrence Shales—Omitting a few lesser limestones and shale beds which have thicknesses so small that we will not consider them here, we come next to a mass of shales which carry a great quantity of sandstone, and hence is very important. They have been named the Lawrence shales. In the vicinity of Lawrence, Kansas, they are about 200 feet thick, or neglecting a thin limestone they may be 300 feet, but southward their thickness increases. Also, very markedly

they grade over into sandstones. These sandstones of themselves are important and prominent throughout all the eastern part of Chautauqua County, and constitute the row of hills and bluffs in the vicinity of Niotaze, Peru and Caney, and from here southward in the Osage territory just west of Bartlesville. They have been called the Chautauqua sandstones, but the person who is trying to keep a clear conception of the strata of the rocks throughout the oil field should think of them as being equivalent to the Lawrence shales, and as lying above the Stanton limestone and below the Oread limestone.

The Chautauqua sandstones are very important as gas producers in the vicinity of Augusta, where they are found in great abundance and called locally the Augusta sands, and as oil producers near Newkirk. It seems that they have a great extent both north and south, and wells drilled in many parts of the country encounter them.

Oread Limestones—First above the Lawrence shales with their important sandstones comes a mass of limestone known in Kansas as the Oread limestones, a common name for Mount Oread at Lawrence. In most places we have here two limestone masses separated from each other by about 20 feet of shale. They extend entirely across the State of Kansas and northwest Missouri into Iowa, and cap a prominent escarpment facing eastward throughout this entire distance.

Near the eastern line of the State they are on top of the hills at Sedan and Elgin and separate the Chautauqua sandstones from the overlying Elgin sandstones of the Oklahoma geologists. They constitute one of the most prominent markers in the upper part of the Pennsylvanian. According to Buttram* they extend but a few miles into Oklahoma and entirely disappear by gradually growing thinner, so that they have little stratigraphic importance in Oklahoma.

*Buttram, Frank, Oklahoma Geol. Sur. Bul. 18, p. 11.

Above the Oread limestones in Kansas is a complex of relatively thin shales and limestone, alternating with each other, which constitute the Shawnee stage of about 400 feet in thickness, and extend upward to the Wabaunsee stage at the bottom of which lies the Burlingame limestones. It is known that these formations thicken to the south end, in general, have their shales grading into sandstones, the most prominent one of which, in Oklahoma, seems to be the Elgin sandstone which lies first above the Oread limestone, and which is used as a geological marker extensively by Oklahoma geologists.

Pawhuska Limestone—Oklahoma geologists use the name Pawhuska limestone to designate a limestone which outcrops near Pawhuska,[1] in Osage County, Oklahoma. This has not been correlated definitely with any of the limestones occuring in Kansas. According to Buttram[2] the Pawhuska limestone lies 556 feet below the Neva limestone in the vicinity of Cushing. This would bring it approximately equivalent with the Burlingame limestone of Kansas, which, in the generalized section for Kansas, is about 500 feet below the Neva limestone. Beede[3] calls it the equivalent of the Deer Creek or Topeka limestone of Kansas. Unfortunately no one has traced the Pawhuska limestone northward from Pawhuska to the State line, so as to learn to a certainty with what Kansas limestone it connects. It may be depended upon, however, that it is in the neighborhood of the Burlingame limestone.

Wabaunsee Stage—The first 500 feet above the Pawhuska-Burlingame limestone in both Kansas and Oklahoma consists of a complex of alternating limestones and shales

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(1) Pawhuska limestone, Smith, Jas. Perrin; Jour. of Geology, Vol. 2, p. 199, 1894.

(2) Buttram, Loc. cited.

(3) Beede, Dr. J. W., Oklahoma State Geol. Sur. Bul. 21, p. 9.

with the shales greatly predominating, to which the name "Wabaunsee Stage" have been given. Nothing herein contained seems to have very much significance stratigraphically or economically, so that we will pass over this distance and enter the Permian. Paleontologists have not definitely decided exactly where the base of the Permian is, but all agree that it is close to the Neva limestone.

Permian—Dr. J. W. Beede* has given us a reliable account of the Neva limestone in Oklahoma. It enters Oklahoma from Kansas a few miles east of the boundary line between Osage and Kay counties, and trends a little west of south, to the northern line of Murray County, near the northwest corner, beyond which it has not been traced. Progressing southward it gradualy changes into sandstone, so that throughout its southern extension it is a sandstone.

Assuming, for the present, that the base of the Permian lies near the Neva limestone, we have the eastern limit of the Permian marked by the great Flint Hills escarpment, which is so prominent in Kansas from the Cottonwood river southward and across into Oklahoma many miles. Immmediately above the Neva we have about 130 feet to the well known Cottonwood limestone, which is so prominent in Kansas, both as a geological marker and as a limestone of great commercial importance. The lower part or base of the Flint Hills is occupied largely with shales alternating with thin limestones for a distance of 150 to 175 feet upwards. Immediately above this lies a great mass of soft, cream-colored limestones with but little shale, which constitute the topmost part of the Flint Hills. The lower one of these limestones has been named the Wreford limestone. It is so heavily charged with flint that in places fully one-fourth of its volume is composed of flint rock. Its thickness varies greatly from north to south, but averages 45 feet or more. Immediately above it we have the Matfield shales 65 feet or

(*) Beede, Dr. J. W., Oklahoma Geol. Sur. Bul. 21, p. 21.

more in thickness, which are followed by another heavy mass of limestone, the lower part of which carries an enormous amount of flint, corresponding to the Wreford limestone. The lowermost of these has been named the Florence Flint and the upper one the Fort Riley limestone. In some places they are separated by thin beds of shale but elsewhere they come so close together that drillers do not recognize a break between them.

Above the Fort Riley we have 60 feet or more of the Doyle shales in Kansas, and then the Winfield limestone, which is about 25 feet in thickness in most places. These formations combined constitute the Chase stage of Kansas geology, named from Chase County, where they are so abundant. The entire thickness varies greatly from place to place, as is shown by the logs of wells drilled at different places from Augusta southward to Ponca City. Some well records show a continuous mass of limestone over 500 feet thick, which would imply that the Doyle shales of the Matfield shales are very thin. It is probable, however, that a carefully kept well record would show that they do not entirely disappear at any one place.

The Flint hills area represents a great monocline with the rock dipping westward along the south line of Kansas at a uniform rate of about 25 feet to the mile, which possibly increases westward and surely increases to the southwest, reaching a dip of 30 feet to the mile or more. Substantially all the development from Augusta southward, including all of the Augusta, Winfield, Arkansas City, Newkirk, Blackwell and Ponca City developments start at or near the upper surface of these formations. West of Arkansas City the overlying Wellington shales are encountered, so that the many deep wells from 3 to 10 miles west and southwest of that place, in Kansas and Oklahoma, have their beginning in the Wellington shales. A careful inspection of the records of these wells implies that the deepest of them, more than

3400 feet, are not very far below the Fort Scott limestones. With the Cherokee shales apparently growing thicker to the west, and known to be 600 feet thick in Chautauqua County, Kansas, it is probable that the Swenson well and others in this vicinity would have to go nearly 4000 feet to reach the bottom of the Cherokee shales. This is an important point, because well drillers in general think they have reached the Mississippian limestone in this part of the field, but evidently they are in error.

Points of Difference—Geologic conditions in Oklahoma in many respects differ materially from those in Kansas, although they have been treated here as though they were substantially the same. The difference consists principally of two characters; first, the dip of the stratified rock to the west and southwest is a little greater in Oklahoma than in Kansas and also gradually becomes greater as one passes southward. This fact is true, however, for the entire area both in Kansas and Oklahoma; second, the greatest and most important difference is that throughout Oklahoma they have much less limestone and much more shale and sandstone, and the formations are correspondingly thickened. In Kansas our best stratigraphic rock leads us to look at the limestones as the important markers, in fact to consider them as so many shelves with the intervening spaces occupied by shales and sandstones. Near the southern part of Kansas, as already pointed out, these limestones begin growing thicker and sandstones especially increased in amount. By the time we have reached the Cushing field in our southward migration we have gotten rid of nearly all the limestone and the formations are correspondingly nearly all sands and shales. The well records from Cushing show upon an average less than two per cent. of limestone for the entire depth, while the average for central Kansas will be about twenty per cent. and the deep wells near Arkansas City on either side of the line show an intermediate per cent. of limestone.

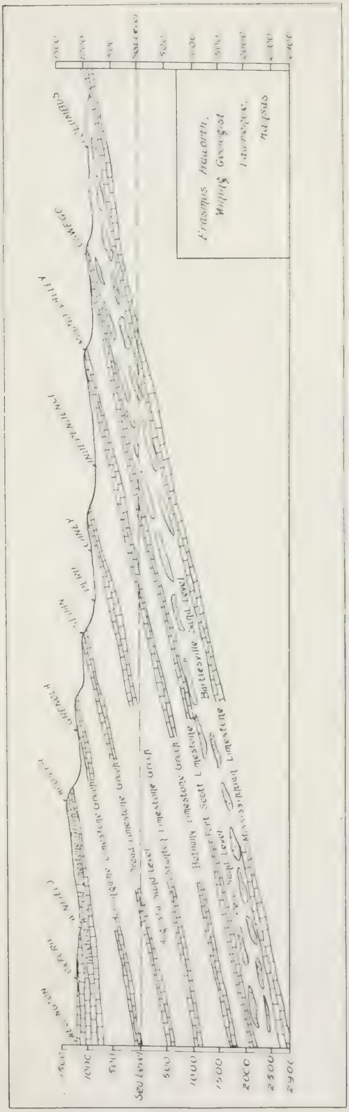


Fig. 1. Map showing a cross section of the Mid Continental Field near South line of Kansas with its principal limestone outcroppings.

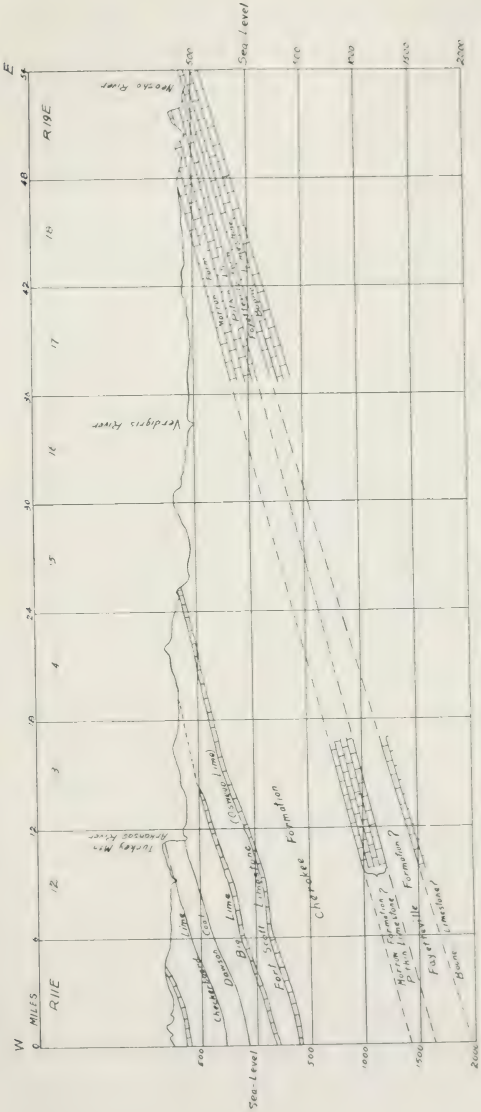
This great change in lithologic conditions makes it very difficult to correlate many of the Oklahoma formations with those in Kansas. It also leaves us under the necessity of using sandstone beds for geologic markers. But with these same sandstone beds having limited horizontal extension, as already pointed out, they become correspondingly unreliable. All of these conditions make it more difficult, therefore, to determine with accuracy the geology of the oil fields in Oklahoma than of the same field farther north. But by keeping in mind the variations as given, fairly reliable inter pretations should not be surrounded with insurmountable difficulties.

Structure—Figure 1 is a cross section of the mid-continental field near the south line of Kansas, extending from Galena to Wellington, showing how the principle limestones outcrop producing, with the soft shales below, great escarpments which trend across the State. It also shows how all the formations dip to the west in almost parallel plains. This section represents only the principle limestones and the vacant spaces between should be thought of as containing the great shale masses with their interbedded sandstones and a few limestones which have been omitted.

Figure 2 is an east-west section copied from Dr. Carl D. Smith's* article on the Glenn pool. This section is about 60 miles south of the Kansas Oklahoma State line, or 75 miles south of Figure 1.

In each of the illustrations the limestone beds are given a slight wavy appearance which is diagrammatical but which represents in a degree the local undulations found in many places here and there throughout the mid-continental field. Usually an oil or gas pool is found immediately under an anticlinal arch, although in some places the deformation of strata is so mild it can hardly be detected. In the most pronounced instances the reverse dip rarely equals 100 feet

* Smith, Dr. Carl D., U. S. Geol. Sur. Bul. 541, p. 43. 1914.



From "The Glenn Oil and Gas Pool and Vicinity, Oklahoma" by C. D. Smith, U S G S Bull 541.

Fig. 2. Map showing a cross section of the Mid Continental Field at a line 60 miles South of the Kansas Oklahoma line.

per mile. With the rock dipping to the west upon an average of from 20 to 30 feet per mile a mild dip to the east or even a horizontal position implies a fold, and should be carefully examined. In Oklahoma, particularly, the great oil and gas pools underlie anticlines in almost every instance. According to Dr. Wood's map (loc. cit. *,) an anticline trending nearly east and west passes through the center of the most productive part of the Glenn pool in Township 17 north, range 12 east, and another one near the north side of Township 18. The Cushing field is on a pronounced anticline, and the wells southeast of Newkirk are on one of the most pronounced anticlines in the entire mid-continental field. In a few instances fairly good oil and gas have been found where the structure was not marked.

It would seem that should one find an anticline in the productive area one might be almost sure production would result from proper prospecting.

The Healdton Area—The surface rocks in Healdton are classed as Permian on the U. S. Geological Survey maps. The production at Healdton is quite shallow, rarely reaching 1000 feet. No detailed correlation work has been made connecting the Healdton field with the area to the north, throughout which detailed geology is known. This leaves it so that little can be said regarding the geology of the Healdton pool. Apparently the oil and gas come from sandstones lying within the Garrison formation.

Wichita Falls—Electra Field—The Electra field is still farther to the southwest and the surface is occupied by Permian rocks. Here, also, we have but little detailed geologic information and cannot connect the Electra field directly with the Oklahoma-Kansas fields. In general it may be said that the difference of detailed geology is quite marked so that a casual observation would make it appear that the two areas are not very much alike. After more elaborate

* Loc. cit. Plate 3.

field work has been done by competent geologists it is entirely possible a definite relation between the two areas may be brought out.

Corsicana Field—The Corsicana oil field lies within the upper Cretaceous. Locally the upper Cretaceous is divided as follows, reading downward:

Navarro Marls	800	feet.
Taylor Marls	1000	"
Austin Chalk	400 to 600	"
Eagle Ford	500 to 600	"
Woodbine	500 to 600	"

The oil seems to lie in sandstones within the Navarro and Taylor marls. Oil wells in the vicinity of Elgin and San Antonio are situated in the same way, which implies the possibility of greatly extending the Corsicana field in that part of the State. Oil at Corsicana is of two different grades and seems to come from two different sands within these marls. That obtained immediately within the city limits and nearby is light in gravity and produces about 60 per cent. distillates, while that which is found two or more miles farther east is much heavier in gravity and much less productive of kerosene and gasoline.

It would be difficult and probably useless to try to correlate these Texas upper Cretaceous formations with similar formations farther north in Oklahoma and Kansas, or in other parts of the United States. They belong to the Cretaceous rocks which were formed in the great inland seas during Cretaceous time, which produced the Cretaceous formations extending from the Gulf region northward far into Canada. These Cretaceous rocks here and there are producers of oil and gas in many parts of the continent, such as Florence, Colorado, both North and South Dakota, where much gas is obtained along with artesian water from the Dakota sandstone; Medicine Hat, Canada, a great gas pool; and the Athabasca river region to the north of Edmonton.

Doubtless no one ever will be able to connect these fields in detail, but is interesting to note that the Corsicana field lies in the same general geologic position with so many other productive areas."

Gas Bearing Strata—The gas bearing strata which when pierced by the drill produces natural gas is sometimes called a "gas vein," a "gas pool," a "gas reservoir," a "gas sand," etc. Practical geologists quite often can locate an anticline or a syncline or other formation where gas or oil is likely to be found but the drill is the only positive way of telling where there is an underlying gas filled strata.

The sand itself must be porous in order to contain gas or oil, and most important of all, the gas bearing strata must be covered by an upper strata of hard non-porous rock, commonly called the "shell" which prevents the gas from gaining an outlet to some upper strata. The tendency of gas is to move upward or parallel to its source until its movement is checked by a non-porous rock or the gas escapes into the atmosphere, as is commonly found at out croppings. Generally the larger the pores or the coarser the sand in a gas bearing strata the shorter the life of the gas from that particular sand.

The area and thickness of a gas bearing strata of sand varies greatly. It may be 40 feet thick in one spot and only 100 feet distant but 2 feet thick or even void of any pores in which the gas is confined. It may be miles in length in one direction while it is but a few hundred feet wide. Its edges may be round in outline or it may be oval. There is absolutely no rule or theory to go by in determining the area or shape of a known gas bearing strata. It can only be determined by the drill.

There may be two gas wells a hundred feet apart with no connection between the gas bearing strata.

Remarkable Natural Gas Reservoirs in North America—No other country has produced more than a small fraction

of the natural gas produced by the United States and Canada.

While mainly confined to the valley of the Mississippi, the gas areas have greatly increased and are now to be found in Ontario, Alberta, New York and California. The main areas of Pennsylvania, West Virginia and Ohio have developed remarkable staying qualities, and considerable new production. These three States produce two-thirds of the total production of this continent. Indiana is the only State that has shown any appreciable falling off in the production of gas. In this State gas was found principally in the Trenton limestone, here, as in the Trenton limestone of Central New York, the supply is soon exhausted. It has been generally considered by geologists that the origin of natural gas is below the Trenton limestone, as this limestone has never shown the proper formation to produce natural gas in paying quantities, probably due to the amount of cement which it carries, which has a great tendency to form pockets.

The mid-continental field has shown a greater increase in production, during the past two years, than any other natural gas area. The Kansas production has dropped off considerably, but it has been offset by the development of new areas, such as Tulsa, Ponca City, Ossage Nation, Choteau, Collinsville, Ada, Duncan and many smaller fields in Oklahoma; Petrolia, Mexia, Laredo, Thurber, Albany and Trickham Texas; Caddo and DeSotto Parish in Louisiana.

The New York and Ontario fields where gas is found in the Medina sandstone have never developed any large wells, but have gradually spread out over an extensive area, and have shown wonderful staying power. Instances are known to the writer where wells in New York state have produced gas in paying quantities from twenty to twenty-five years, and are still good producers.

The Alberta field has developed many exceptionally large wells. The great volume already produced can be taken as a

very good indication of the Alberta field as a gas-producing province.

Small gas areas are to be found in Illinois, Kentucky, California, Wyoming, Alabama, Colorado, New Mexico, Oregon and South Dakota. None of these fields is fully developed, consequently it is impossible to predict what the future will produce.

In foreign countries there is some gas produced in Russia, Persia, Roumania, Galicia, India, Japan and Mexico. England produces a limited amount.

In the year 1913 the total production of natural gas in the United States and Canada was nearly six hundred billion cubic feet.

It is estimated that not less than twelve millions of our inhabitants are enjoying the benefits of this ideal fuel, as a source of heat, light and power.

Many of the natural gas pools in the United States are associated with the petroleum producing areas, to which they often form a fringe or border near by, the gas occupying the higher portions of the same strata that contain the petroleum. There are, however, numerous areas that produce large quantities of natural gas that are completely isolated from any petroleum production.

Productive Natural Gas Horizons—The chart of productive natural gas horizons shown on the following page was prepared with a view of showing the various oil and gas sands with reference to their age and position in the stratified rocks forming the earth's crust. Owing to the fact that some of the oil fields have not been given thorough geological study and also that geologists are not yet certain regarding the age of several of the formations, this chart is of course approximated. Asterisks (*) indicate uncertainty.

TABLE SHOWING
PRODUCTIVE NATURAL GAS HORIZONS

Era	Geological System	Geological Series of Group	Producing Formation or Sand	Locality where Productive
CENOZOIC	Quarter-nary	Recent Series	Alluvial Deposits	Beaumont, Tex. Jennings, La.
	Tertiary	Pliocene*		
		Miocene Series — Upper Mio-cene	Jacalitos Formation	Coalinga, Cal. McKittrick-Sunset Cal.
			Fernando Formation	Santa Clara River, Cal. Los Angeles, Cal.
		Miocene Series — Middle Mio-cene	Monterey Shale	Santa Maria, Cal. Summerland, Cal.
			Puente Formation	Los Angeles, Cal. Salt Lake District, Cal.
		Miocene Series — Lower Mio-cene	Vaqueros Sandstone	Coalinga, Cal. McKittrick-Sunset Cal. Santa Clara River, Cal.
		Eocene Series	Tejon Formation	Coalinga, Cal.
			Sespe Formation	Santa Clara River, Cal.
MESOZOIC	Cretac-eous	Upper Cretac-eous	Chico Formation	Coalinga, Cal.
			Mancos Shale	Colorado Lander, Wyo. Wind River, Wyo.
			Dakota Sandstone	North Dakota Alberta, Canada (Gas)
			Webberville Formation	Corsicana, Tex.
			Aspen Formation	Spring Valley, Wyo.
			Colorado Formation	Big Horn Basin, Wyo.
			Wall Creek Sandstone (Lentil of Benton Shale)	Salt Creek, Wyo.
			Nacatoch Sand	Caddo, La. (Gas)
			Woodbine Sand	Caddo, La. (Oil)
		Lower Cretaceous	Trinity Sand	Medill, Okla.
	Jurassic		Sundance Formation	N. E. Wyoming
	Triassic	*	Chugwater Formation	Wyoming

The following table by F. H. Oliphant shows the strata in descending order, that are known to contain natural gas in greater or less quantity in the localities named, beginning with Pittsburgh coal, which caps the upper barren measures of the carboniferous, and extending to the Quebec group of the Cambrian. The distance from the Pittsburgh coal to the lower Trenton is given approximately, and the approximate intervals can be found by subtracting one from the other.

It must not be inferred that all of the strata named are universally productive, but that the horizons in the localities named are productive.

In the northeastern portion of the Mississippi Valley natural gas occurs principally in the strata beginning with the higher carboniferous down to the bottom of the Trenton, a distance of over 9,000 feet. The rocky reservoirs, and strata associated with them, vary considerably in thickness and texture. This section is compiled from records of wells near McDonald, Allegheny County, Pennsylvania, and extends northeast to central New York, where the lower strata are productive.

The fact that the very lowest rocks of the Trenton limestone yield the greatest known gas pressure, amounting in New York to 1,500 pounds to the square inch, indicates that all of these different horizons are supplied from a common deep-seated source, and that the gas is not indigeneous to the strata in which it is found stored. This common source is probably deeply covered by Paleozoic rocks which have been more or less disturbed by folds that have produced slight fractures in the strata. These have served as vents for the passage of natural gas into the overlying porous strata, where it is found to-day. Many of these sands contain large quantities of petroleum, but pools of natural gas are much more generally distributed and occupy a much larger area than the pools of petroleum, both of which have a common origin.

PRODUCTIVE NATURAL GAS HORIZONS

(By F. H. Oliphant)

Geological Equivalent	Natural Gas Horizons	Locality Where Productive	Approx. Depth Below Pittsburgh Coal
			Feet
Conemaugh or Barren measures XIV	Pittsburgh sand, capping Pittsburgh coal	West Virginia	0
	Connellsville sand	West Virginia	40
	Morgantown sand	West Virginia	80
	"Hurry up" sand	S. W. Pennsylvania and West Virginia	325
Allegheny or Lower productive XIII	Mahoning or Dunkard sand	S. W. Pennsylvania and West Virginia	485
	Upper Freeport or second Cow Run sand	S. E. Ohio, S. W. Pennsylvania and W. Va.	630
	Ferriferous limestone	Not productive	850
Pottsville XII	Tionesta, Homewood or Johnson Run sand	S. E. Ohio, S. W. Pennsylvania and W. Va.	920
	Upper Conoquenessing or upper salt sand	S. E. Ohio, S. W. Pennsylvania and W. Va.	970
	Lower Conoquenessing or middle salt sand	S. E. Ohio, S. W. Pennsylvania and W. Va.	1,060
	Sharon Conglomerate, Orlean lower salt or Maxon sand	Kansas and Indian Territory, S. E. Ohio, S. W. Pennsylvania, West Virginia and E. Kentucky	1,140
Mauch Chunk XI	Mountain limestone	Not productive	1,225
	Keener sand, sandy limestone	S. E. Ohio and West Virginia	1,345
Pocono X	Big Injun or Sub Olean sand	West Virginia, S. W. Pennsylvania, S. E. Ohio and E. Kentucky	1,375
	Squaw sand	West Virginia, S. W. Pennsylvania, S. E. Ohio and E. Kentucky	1,465

PRODUCTIVE NATURAL GAS HORIZONS (*Continued*)

Geological Equivalent	Natural Gas Horizons	Locality Where Productive	Approx. Depth Below Pittsburgh Coal
			Feet
Catskill IX or upper Devonian	Upper gas sand	S. W. Pennsylvania	1,535
	Berea or Butler County gas sand	S. W. Pennsylvania, West Virginia, Ohio and Kentucky	1,730
	Devonian or Ohio shales	W. New York, N. W. Pennsylvania, N. E. Ohio, W. Kentucky and S. Indiana	1,750
	First sand or Gantz (100-foot sand)	W. Pennsylvania, West Virginia and S. W. Ohio	1,855
	50-foot sand	W. Pennsylvania and West Virginia	1,910
	Second or 30-foot sand	W. Pennsylvania and West Virginia	2,010
	Gray, Stray or Boulder sand	W. Pennsylvania and West Virginia	2,070
	Third or Gordon sand	W. Pennsylvania, West Virginia and S.E. Ohio	2,130
	Stray third sand	W. Pennsylvania and West Virginia	2,145
	Fourth sand	S. W. Pennsylvania and West Virginia	2,200
	Fifth sand	S. W. Pennsylvania and West Virginia	2,260
	Bayard sand	S. W. Pennsylvania and N. West Virginia	2,420
Lower Devonian VIII	Elizabeth or sixth sand	S. W. Pennsylvania and N. West Virginia	2,590
	Warren first sand	N. W. Pennsylvania	2,685
	Warren second sand	N. W. Pennsylvania	2,800
	Clarendon or Tiona sand	N. W. Pennsylvania	2,885
	Speechley sand	N. W. Pennsylvania	3,000
	Balltown or Cherry Grove sand	N. W. Pennsylvania and W. New York	3,120

PRODUCTIVE NATURAL GAS HORIZONS *(Continued)*

Geological Equivalent	Natural Gas Horizons	Locality Where Productive	Approx. Depth Below Pittsburgh Coal
			Feet
Lower Devonian VIII	Sheffield or Copper sand	N. W. Pennsylvania and W. New York	3,320
	Bradford or Deer Lick sand	N. W. Pennsylvania and W. New York	3,430
	Elk sand or Waugh and Porter sand	N. W. Pennsylvania and W. New York	3,645
	Kane sand	N. W. Pennsylvania and W. New York	3,775
	Black shales bottom of Devonian	N. W. Kentucky, S. Indiana	5,325
	Hamilton limestone	S. W. Ontario, Canada	5,330
	Corniferous	New York and S. W. Ontario, Canada	5,625
	Oriskany sand	S. Indiana, S. Ontario, central New York	5,660
Silurian	Guelph limestone	S. Ontario, W. New York	5,700
	Niagara limestone	S. Ontario, W. New York and Indiana	5,820
	Clinton limestone	S. E. and central Ohio and S. E. Ontario	5,985
	Medina red sand	S. E. Ontario, W. New York and Ohio	6,085
	Medina upper white sand	S. E. Ontario and W. New York	6,185
	Medina white sand	Central New York	6,240
	Trenton limestone, upper portion	Ohio, Indiana and Kentucky	8,700
	Trenton limestone, lower portion	S. E. and central Ontario and N. central New York	9,225
Cambro-Silurian	Calciferous and Potsdam sand	S. E. Ontario and central New York	.....
Cambrian	Quebec group, sands and shale	Alabama, Georgia and N. W. Newfoundland	.....

THE FIRST OIL WELL IN AMERICA AT TITUSVILLE, PA., AUGUST 27, 1859.

Fig. 3. THE DRAKE WELL.

Depth 69½ feet. Produced 20 barrels per day for one year. Man with silk hat, Col. E. L. Drake. Man on his left, Peter Wilson, his friend. Boys on the right, sons of Wm. Smith, the driller, who assisted their father. Commenced drilling May 20, 1859; completed Saturday, August 27, 1859. Photograph taken August 17, 1861.

History of Natural Gas—Natural gas was known to exist in China, Persia and British India for many centuries, although it was never put to commercial use. It appeared as leakage from gas-bearing strata through crevices in the ground, and when lighted by the natives, it was worshipped as a fire "god."

At a burning well near Baku, Russia, are the ruins of an old Parsee temple, dedicated to the God of Fire.

In this country, as early as 1775, George Washington dedicated to his country, as a national park, a tract of land which he had preempted, in West Virginia, containing a burning spring. This, too, was leakage from a crevice in the ground.

The first discovery of natural gas by drilling in the United States occurred through the drilling of shallow wells for salt in Ohio and West Virginia, and probably dates back to early in the nineteenth century.

Along the Muskingum River in Ohio in the early thirties many salt wells were drilled to a shallow depth of from three hundred to four hundred feet. These wells were located along the river from Stockport to Duncan and the making of salt became an industry of importance.

Rufus Stone, one of the first operators in the salt making business at McConnelsville, in the Morgan field, in drilling for salt struck a vein of natural gas strongly impregnated with sulphur, which caused the drillers to exclaim "we have drilled through into hell."

At first Mr. Stone considered the well a failure but later Captain Harry Stull solved the problem for him, making the gas boil the water in making the salt. This was continued for forty years.

The first actual use of natural gas for light occurred in Fredonia, New York, in 1826, but it was not until 1872 that Titusville, Pennsylvania, was piped for natural gas for domestic purposes, the gas being delivered through a two-inch line from the Newton well about five miles north of Titusville.

From that time the natural gas industry has had a phenomenal growth, increasing from a domestic service to perhaps a hundred people to the present total of about two million consumers, serving approximately twelve million people.

First Use of Artificial Gas—In the year 1812 the Gas Light and Coke Company of London obtained a charter to supply gas to that city. William Murdock was the inventor of coal gas and lighted his home with it in the year 1792. He was connected with the above mentioned company when they first applied for their charter, three years before it was finally granted.

At the time of the first application before the House of Parliament, a great deal of ridicule was directed toward Mr. Murdock and his company.

"Do you mean to tell us," asked one member, "that it will be possible to have a light without a wick?"

To which Murdock answered in the affirmative, for the best of all reasons—that he himself had produced a light with gas.

"Ah! my friend," said the representative of the people in the House, "you are trying to prove too much."

Men, talented and educated, heaped ridicule upon the work of that little band of heroes who foregathered at Soho, Birmingham. Sir Walter Scott, great as was his admiration for James Watt, made various smart jokes about the absurdity of lighting London with smoke. People implicitly believed that the gas was carried through the pipes on fire, and they foresaw awful results from red-hot metal.

To-day the Gas Light and Coke Company of London has a capital stock of $150,000,000, and in the year 1911 burned two million tons of coal and made about twenty-seven billion feet of gas.

Natural Gas in Fredonia, N. Y.—The "*Penny Magazine*," a London weekly, on August 26, 1837, published an

article taken from "*Brewster's Journal*," under date of 1830 and which is reprinted herewith as a matter of general interest:

VILLAGE LIGHTED BY NATURAL GAS

The Village of Fredonia in the Western part of the State of New York presents this singular phenomenon. I was detained there a day in October of last year, and had an opportunity of examining it at leisure. The village is forty miles from Buffalo, and about two miles from Lake Erie; a small but rapid stream, called the Canadoway, passes through it, and after turning several mills discharges itself into Lake Erie below; near the mouth is a small harbour with a lighthouse.

While removing an old mill which stood partly over the stream in Fredonia, three years since, some bubbles, were observed to break frequently from the water, and on trial were found to be inflammable. A company was formed, and a hole an inch and a half in diameter, being bored through the rock, a soft, fetid limestone, the gas left its natural channel and ascended through this. A gasometer was then constructed, with a small house for its protection, and pipes being laid, the gas is conveyed through the whole village. One hundred lights or less are fed from it, at an expense of one dollar and a half yearly for each. The flame is large, but not so strong or brilliant as that from gas in our cities; it is, however, in high favour with the inhabitants. The gasometer, I found on measurement, collected eighty-eight feet in twelve hours during the day, but the man who has charge of it told me that more might be procured with a larger apparatus. About one mile from the village, and in the same stream, it comes up in quantities four or five times as great. The contractor for the lighthouse purchased the right to it, and laid pipes to the lake; but found it impossible to make it descend, the difference in elevation being very great. It preferred its own natural channels, and bubbled up beyond the reach of its gasometer. The gas is carburetted hydrogen, and is supposed to come from beds of bituminous coal; the only rock visible, however, here, and to great extent on both sides along the Southern shore of Lake Erie, is fetid limestone.

Deepest Drilled Wells—The deepest drilled hole is at Czuchow, Silesia, which reached a depth of 7,349 feet. Its diameter is about 17 inches at the top and about 2 inches at the bottom, where the temperature is about 182 deg. fahr. It cost $18,241 and was completed in 1893 after one and one-half years of work.

The deepest diamond drilled well is located at Dornkloof, sixteen miles east of Randfontein, South Africa. It is 5,560 feet deep, 2 inches in diameter at the top and 1 3-8

inches at the bottom, and was completed in 1904, after fourteen months of actual work.

The deepest well drilled in America is located at Candor, Washington County, Pennsylvania, and is being put down by the People's Natural Gas Company of Pittsburgh, Pennsylvania. At the present writing, June, 1915, the drillers have a fishing job at a depth of 7181 feet. The following give a few facts of work:

Dimensions of Derrick

Base 26 feet.
Derrick 90 feet.
Bull Wheel Shaft 2 feet.
Bull Wheel Gudgeons 5½″ Steel.
Crown Pulley Gudgeons 6″ Steel.
Band Wheel Shaft 6″.
Wrist Pin 4″.
Band Wheel 18″ x 12 feet.
Belt 8 ply 16″ x 105 feet.
Engine 14″ x 14″ 52-h. p.
2—30-h. p. Boilers.

Amount of Casing Used

232	feet—13″	Casing.
953	" —10″	"
1,969	" — 8¼″	"
6,053	" — 6⅝″	"
6,102	" — 5¾″	"
6,265	" — 4½″	"

Dimensions of Hole where it was reduced

16 inch	Hole	232	Feet.
13 "	"	953	"
10 "	"	1,969	"
8¼ "	"	6,053	"
5¾ "	"	6,102	"

Depth to which Well was drilled with a 2¼″ manilla cable,
Length, 3,720 Feet.

Cables Used in Drilling Well

1—2¼″ Manilla Cable 2,000 feet.
1—2¼″ " " 3,000 "
1—1″ x 7,000 feet Wire.
1—1⅛″ to ⅞″ 8,000 ft. Wire.
1—1″ 8,000 ft.
1—1″ 8,000 ft.
1—1″—1⅛″—1⅞″ 8,000 ft. Taper.

Sand Lines

1—½″ x 3,500 feet.
1—½″ x 7,000 feet.
1—$\frac{9}{16}$″ x 8,000 feet.
1—$\frac{9}{16}$″ x 8,000 feet.

Depth at which Explosions of Gas occurred

At 4,850 feet.
" 4,870 "
" 5,900 "
" 5,905 "
" 5,910 "
" 5,915 "
" 6,060 "

Record of Temperatures Taken in Well

At 5,150 feet	110 degrees fahr.
" 5,220 "	120 " "
" 5,800 "	140 " "
" 6,000 "	150 " "
" 6,095 "	156 " "

R. A. GEARY WELL No. 770
11o Below Coal

Formation	*Top*	*Bottom*
Conductor	16′	....
13″ Casing	232	....
Limestone	450	470′
Slate	470	595
Freeport Coal	595	600
Water at	600	....
Gas	760	....
Salt Sand	734	950
Gas	912	.....
Pencil Cave	950	953
Big Lime	953	982
10″ Casing	953	.....
Big Injun Sand	982	1,241
Gas	1,052	.....
Squaw Sand	1,378	1,392
Gas	1,379	.....
Sand	1,610	1,622
Hundred Foot Sand	1,794	1,817
Gas	1,797	.....
Thirty Foot Sand	1,910	1,925
Gas	1,912	.....
Gordon Stray	1,968	1,971
8¼″ Casing	1,969	.....
White Slate	1,971	2,990
Limestone	2,990	3,210
White Slate	3,210	3,440
Reduced Hole	3,440	.....
Limestone	3,440	3,450
White Slate	3,450	4,100
Sand and Lime	4,100	4,170
White Slate	4,170	4,520
Black Slate	4,520	4,550
White Slate	4,550	5,200
Black Slate	5,200	5,320

R. A. GEARY WELL No. 770—(*Continued*)

Formation	*Top*	*Bottom*	
Black Shale	5,320	5,520	
White Slate	5,520	5,660	
Limestone	5,660	5,680	(Supposed Guelph)
Black Lime	5,680	5,788	(" Niagara)
Black Slate	5,788	6,008	
Black Lime	6,008	6,023	
Flint	6,023	6,045	
Gray Sand	6,045	6,200	
6⅝" Casing	6,053	.....	
Water and Gas	6,060	.....	
Brown Sand	6,200	6,260	
Water	6,260	6,265	
White Sand	6,260	6,270	
Brown Sand	6,270	6,315	
Black Lime	6,315	6,395	
Sand and Black Flint	6,395	6,405	
Black Lime	6,405	6,515	
White Sand	6,515	6,530	
Gas	6,522	.....	
Black Limestone	6,530	6,610	
Gray Limestone	6,610	6,700	
Rock Salt	6,700	6,708	
Lime and Sand	6,708	6,775	
Rock Salt	6,775	6,785	
Limestone	6,785	6,830	
Rock Salt	6,830	6,840	
Lime and Sand	6,840	6,860	
Rock Salt	6,860	6,865	
Limestone	6,865	6,870	
Rock Salt	6,870	6,875	
Limestone	6,875	6,895	
Rock Salt	6,895	6,900	
Limestone	6,900	6,910	
Rock Salt	6,910	6,925	
Limestone and Sand	6,925	7,020	
Salt and Lime Shells	7,020	7,040	
Sand and Lime	7,040	7,181	

A "Freak" Gas Well—A very interesting producing gas well was discovered in February, 1915, in the Kansas field.

The well was located in the southern end of a well-defined producing area in which all of the wells previously drilled had been productive in a 1,600 foot sand of close formation, giving the wells a relatively small open-flow capacity, the average for the flow being about 1,000,000 cu. ft. a day, and the maximum not more than 4,000,000 cu. ft. for wells previously drilled.

The other wells in the field struck the sand very uniformly at the level indicated by geological survey.

The sand was struck unexpectedly about six o'clock in the evening about fifty feet above the expected level, and the rush of gas from the well blew the tools out of the hole through the crown-block of the derrick, and about four hundred feet in the air, the tools coming down within twenty feet of the hole, and penetrating eight feet of soil and three feet of limestone, twisting the stem in two distinct cork-screws from the force of the impact. The open flow capacity of the well twelve hours later was about thirty million feet per day, and twenty-six hours later was thirteen million feet per day, but subsequent calculations show that the first flow could not have been less than seventy-five million feet.

The interesting feature of this well was not its enormous flow, but the fact that when closed in twenty-six hours afterward it made only about fifty pounds rock pressure which gradually built up over a period of two weeks to the original pressure of the sand of about five hundred and fifty pounds. Careful calculations from an orifice meter installed on the line from this well, together with a recording gauge record of the pressures of the well, show that this well had penetrated a cavity in the rocks of between one-half and three-quarter million cubic feet volume, with a crevice or passage through which gas feeds from the main sand body at the rate of about two to three million feet per day.

In actual operation this well is used as a reservoir and allowed to fill up to the maximum pressure when the entire contents of this cavity is available and can be used in a few hours, or a day, or two days, as emergency requires.

If in constant use the well would not be worthy of special note, but as an emergency reservoir from which ten to fifteen million feet can be taken in a few hours, it is of untold value in the maintenance of good service under trying conditions which confront every gas company at times.

The rock pressure in the field is about 550 lb.

Altitudes and Atmospheric Pressures of Gas Fields in the United States—The following table, from the United States Geological Survey, gives the altitudes, together with the average atmospheric pressure, in or near the different gas fields in the United States.

TOWN	FEET ABOVE SEA LEVEL	AVERAGE ATMOSPHERIC ARESSURE	TOWN	FEET ABOVE SEA LEVEL	AVERAGE ATMOSHHERIC PRESSURE
Ashtabula, O.	688	14.33	Johnstown, Pa.	1184	14.07
Arkansas City, Kas.	1064	14.13	Joplin, Mo.	1018	14.16
Astoria, Ore.	50	14.67	Kansas City, Mo.	748	14.30
Alliance, O.	1083	14.12	Lexington, Ky.	975	14.17
Bradford, Pa	1464	13.92	Los Angeles, Cal.	265	14.56
Batavia, N. Y.	895	14.22	Laredo, Tex.	806	14.26
Baldwinsville, N. Y.	390	14.49	Lima, O.	859	14.24
Beaumont, Tex.	26	14.69	Little Rock, Ark.	263	14.56
Boulder, Col.	5308	12.34	Muncie, Ind.	948	14.19
Bakersfield, Cal.	432	14.47	Mobile, Ala.	69	14.66
Bowling Green, Ky.	466	14.45	Marion, O.	979	14.17
Buffalo, N. Y.	588	14.38	Muskogee, Okla.	599	14.38
Birmingham, Ala.	596	14.38	Pittsburgh, Pa.	745	14.30
Charleston, W. Va.	603	14.37	Parkersburg, W. Va.	574	14.39
Chanute, Kas.	910	14.21	Port Huron, Mich.	633	14.36
Cincinnati, O.	501	14.43	Pierre, S. D	1438	13.93
Corning, N. Y.	942	14.19	Pueblo, Col.	4669	12.72
Cleveland, O	583	14.38	Robinson, Ill.	508	14.43
Columbus, O	748	14.30	Red Bluff, Cal.	307	14.53
Corsicanna, Tex.	427	14.47	Raton, N. M.	6620	11.79
Claremore, Okla.	604	14.37	Roystone, Pa.	1465	13.92
Dallas, Tex.	466	14.45	Silver Creek, N. Y.	623	14.36
Dunkirk, N. Y.	598	14.38	Shreveport, La	198	14.59
Des Moines, Ia.	800	14.27	San Antonio, Tex.	683	14.37
Erie, Pa.	686	14.33	Salt Lake City, Utah	4228	12.73
Evanston, Wyo.	6835	11.69	Santa Anna, Cal.	137	14.63
Fairmont, W. Va.	888	14.22	Tulsa, Okla.	701	14.32
Fort Worth, Tex.	623	14.36	Texarkana, Tex.	303	14.54
Fort Scott, Ark.	467	14.45	Trinidad, Col.	5820	12.12
Huntington, W. Va.	566	14.39	Toledo, O	583	14.39
Huntsville, Ala.	612	14.37	Vincennes, Ind	431	14.47
Hot Springs, Ark.	718	14.31	Warren, Pa.	1200	14.06
Henrietta, Tex.	915	14.21	Wheeling, W. Va.	637	14.36
Indianapolis, Ind.	709	14.32			

Temperature Averages of Various Gas Fields and Cities Using Natural Gas

City	Average Annual Temperature	Average Daily Minimum in Winter	Average Daily Maximum in Summer	Average Humidity (%)
Astoria ....Ore.	51	. .	. .	. .
Abilene ......Tex.	64	35	91	64
Buffalo.......N. Y.	47	20	75	73
Birmingham ..Ala.	64	38	90	. .
Beaumont ....Tex.	69	. .	. .	. .
Bakersfield ...Cal.	66	. .	. .	
Cumberland ...Md.	51	22	86	. .
Cleveland.....Ohio	49	22	77	73
Columbus.....Ohio	52	24	83	73
Cincinnati....Ohio	55	27	84	69
Corpus Christi, Tex.	70	51	86	82
Charleston..W. Va.	58	. .	. .	. .
Chanute .....Kan.	56	. .	. .	. .
Carlsbad.. N. Mex.	63	. .	. .	. .
Des Moines.... Ia.	49	14	83	72
Dallas ....Tex.	65	33	94	. .
Detroit.......Mich.	48	20	79	75
Erie............Pa.	47	22	76	76
Fairmont ...W. Va.	54	. .	. .	. .
Ft. Smith ....Ark.	61	31	90	70
Ft. Scott.... Kans.	56	. .	. .	. .
Hot Springs...Ark.	62	. .	. .	. .
Henrietta... .Tex.	63	. .	. .	. .
Huntington. W. Va.	54	. .	. .	. .
Indianapolis...Ind.	55	23	84	70
Jamestown...N. Y.	47	18	78	.
Johnstown......Pa.	51	. .	. .	. .
Joplin.........Mo.	57	. .	. .	. .
Kansas City ..Mo.	54	23	85	70
Lexington.... Ky.	55	28	84	69
Laramie .....Wyo.	40	10	75	60
Los Angeles...Cal.	62	45	82	71
Louisville ....Ky.	57	29	86	67
Little Rock ..Ark.	62	35	89	72
Lima..........Ohio	50	. .	. .	
Marion........Ohio	51	19	86	. .
Mobile ....Ala.	67	45	89	81
Nashville ...Tenn.	59	32	87	71
Muskogee ...Okla.	60	. .	. .	. .
Pittsburgh......Pa.	53	25	83	72
Portsmouth...Ohio	56	24	87	. .

Temperature Averages of Various Gas Fields and Cities Using Natural Gas--Continued

City	Average Annual Temperature	Average Daily Minimum in Winter	Average Daily Maximum in Winter	Average Humidity (%)
Pueblo ...... Colo.	52	17	87	48
Port Huron .. Mich.	46	18	76	77
Pierre .... S. D.	47	10	85	64
Parkersburg. W. Va.	54	26	84	76
Red Bluff ..... Cal.	63	39	93	57
San Francisco Cal.	56	46	65	80
Shreveport .... La.	66	40	92	73
San Antonio .. Tex.	69	44	93	67
Toledo........ Ohio	50	21	79	74
Texarkana .... Ark.	64	..	..	..
Tulsa .... Okla.	60	..	..	..
Wheeling.... W. Va.	56	..	..	..
Warren......... Pa.	47	..	..	..
Wichita ..... Kans.	56	24	88	68

Atmospheric Pressure—The average pressure at the sea level is 29.95 inches of mercury, equal to 14.70 pounds per square inch. Under favorable conditions above the sea level the pressure decreases as shown by the following table.

Altitude Above Sea Level.	Barometric Pressure	
	Lb. per Sq. In.	Inches of Mercury
0	14.70	29.95
500	14.43	29.40
1000	14.17	28.87
1500	13.90	28.32
2000	13.63	27.77
2500	13.37	27.24
3000	13.10	26.69
4000	12.67	25.81
5000	12.20	24.85
6000	11.73	23.89

2.0374 inches of mercury or 27.68 inches of water at 62 deg. fahr. equal one pound. Mercury is therefore 13.58 times heavier than water.

In higher altitudes there is an increase in the number of feet in elevation per inch of mercury.

Table Showing the Weight per 1000 Cu. Ft. of Air and Natural Gas of 0.6 Specific Gravity at Different Temperatures and at a Pressure of 14.65 Lb. per Sq. In. Absolute Corresponding to 4 Ounces Above 14.4 Lb. Atmospheric Pressure.

Temperature Deg. Fahr.	Weight in Pounds		Temperature Deg. Fahr.	Weight in Pounds	
	1000 Cu. Ft. of Gas of 0.6 Sp. Gr.	1000 Cu. Ft. of Air		1000 Cu. Ft. of Gas of 0.6 Sp. Gr.	1000 Cu. Ft. of Air
0	51.61	86.05	110	41.66	69.43
10	50.52	84.23	120	40.94	68.23
20	49.47	82.47	130	40.25	67.08
32	48.27	80.45	140	39.58	65.95
40	47.49	79.17	150	38.93	64.88
50	46.56	77.61	160	38.30	63.83
60	45.66	76.11	170	37.69	62.82
70	44.80	74.67	180	37.10	61.84
80	43.97	73.29	190	36.53	60.88
90	43.18	71.96	200	35.98	59.96
100	42.40	70.67	212	35.34	58.89

Production and Consumption*—The following tables give, by States, the total value of the natural gas produced in the entire country from 1884 to 1913, inclusive:

PRODUCTION

State	1886	1887	1888	1889	1890	1891	1892
Pennsylvania	$9,000,000	$13,749,500	$19,282,375	$11,593,989	$9,551,025	$ 7,834,016	$7,376,281
New York	210,000	333,000	332,500	530,026	552,000	280,000	216,000
Ohio	400,000	1,000,000	1,500,000	5,215,669	4,684,300	3,076,325	2,136,000
West Virginia	60,000	120,000	120,000	12,000	5,400	35,000	70,500
Illinois	4,000	....	....	10,615	6,000	6,000	12,988
Indiana	300,000	600,000	1,320,000	2,075,702	2,302,500	3,942,500	4,716,000
Kansas	6,000	....	....	15,873	12,000	5,500	40,795
Missouri	....	....	....	35,687	10,500	1,500	3,775
California	....	....	....	12,680	33,000	30,000	55,000
Kentucky and Tennessee	....	....	....	2,580	30,000	38,993	43,175
Texas and Alabama	....	....	....	1,728	....	....	100
Arkansas and Wyoming	....	....	....	375	....	250	100
Other	32,000	15,000	75,000	1,600,175	1,606,000	250,000	200,000
Total	10,012,000	15,817,500	22,629,875	21,107,099	18,792,725	15,500,084	14,870,714

In 1884 Pennsylvania produced 1,100,000; other states 360,000; totaling 1,460,000.

In 1885 Pennsylvania produced 4,500,000; other states 357,200; totaling 4,857,200.

*Hill, B. The Production of Natural Gas in 1913.

PRODUCTION (*Continued*)

State	1893	1894	1895	1896	1897	1898	1899
Pennsylvania	$6,488,000	$6,279,000	$5,852,000	$5,528,610	$6,242,543	$6,806,742	$8,337,210
New York	210,000	249,000	241,530	256,000	200,076	229,078	294,593
Ohio	1,510,000	1,276,100	1,255,700	1,172,400	1,171,777	1,488,308	1,866,271
West Virginia	123,000	395,000	100,000	640,000	912,528	1,334,023	2,335,864
Illinois	14,000	15,000	7,500	6,375	5,000	2,498	2,067
Indiana	5,718,000	5,437,000	5,203,200	5,043,635	5,009,208	5,060,969	6,680,370
Kansas	50,000	86,600	112,400	124,750	105,700	174,640	332,592
Missouri	2,100	4,500	3,500	1,500	500	145	290
California	62,000	60,350	55,000	55,682	50,000	65,337	86,891
Kentucky and Tennessee	68,500	89,200	98,700	99,000	90,000	103,133	125,745
Texas and Alabama	50	50	20	......	......	765	8,000
Arkansas and Wyoming	100	100	100	60	40	......	......
Utah	500	500	20,000	20,000	15,050	7,875	......
Colorado	......	12,000	7,000	4,500	4,000	3,300	1,480
South Dakota	......	......	......	......	......	......	3,500
Indian Territory and Oklahoma	......	......	......	......	......	......	......
Louisiana	......	......	......	......	......	......	......
Other	100,000	50,000	50,000	50,000	20,000	20,000	......
Total	14,346,250	13,954,400	13,006,650	13,002,512	13,826,422	15,296,813	20,074,873

PRODUCTION (*Continued*)

STATE	1900	1901	1902	1903	1904	1905	1906
Pennsylvania	$10,215,412	$12,688,161	$14,352,183	$16,182,834	18,139,914	$19,197,336	$18,558,245
New York	335,367	293,232	346,471	493,686	522,575	623,251	672,795
Ohio	2,178,234	2,147,215	2,355,458	4,479,040	5,315,564	5,721,462	7,145,809
West Virginia	2,959,032	3,954,472	5,390,181	6,882,359	8,114,249	10,075,804	13,735,343
Illinois	1,700	1,825	1,844	3,310	4,745	7,223	87,211
Indiana	7,254,539	6,954,566	7,081,344	6,098,364	4,342,409	3,094,134	1,750,715
Kansas	356,900	659,173	824,431	1,123,849	1,517,643	2,261,836	4,010,986
Missouri	547	1,328	2,154	7,070	6,285	7,390	7,210
California	79,083	67,602	120,648	104,521	114,195	133,696	134,560
Alabama							
Texas	286,243	270,871	365,656	390,601	322,404	14,409	150,695
Louisiana						1,500	
Kentucky	20,000	18,577	14,953	13,851	14,082	237,290	287,501
Tennessee	....	....	....	2,460	6,515	300	300
Arkansas and Wyoming	....	....	....	....	....	21,135	34,500
Colorado	1,800	1,800	1,900	14,140	14,300	20,752	22,800
South Dakota	9,817	7,255	10,280	10,775	12,215	15,200	15,400
Oklahoma	....	....	....	....	....	130,137	259,862
North Dakota	....	....	360	1,000	49,665	....	....
Oregon	....	....	....	....	....	....	....
Iowa	....	....	....	....	....	....	....
Total	23,698,674	27,066,077	30,867 863	35,807,860	38,496,760	41,562,855	46,873,932

PRODUCTION (*Continued*)

State	1907	1908	1909	1910	1911	1912	1913
Pennsylvania	$18,844,156	$19,104,944	$20,475,207	$21,057,211	$18,010,796	$18,539,672	$21,695,845
New York	766,157	959,280	1,222,666	1,678,720	1,418,767	2,343,379	2,425,633
Ohio	8,718,562	8,244,835	9,966,938	8,626,954	9,367,347	11,891,299	10,416,699
West Virginia	16,670,962	14,837,130	17,538,565	23,816,553	28,451,907	33,324,475	34,164,850
Illinois	143,577	446,077	644,401	613,642	687,726	616,467	574,015
Indiana	1,572,605	1,312,507	1,616,903	1,473,403	1,192,418	1,014,295	948,278
Kansas	6,198,583	7,691,587	8,293,846	7,755,367	4,854,534	4,336,635	3,288,394
Missouri	17,010	22,592	10,025	12,611	10,496	11,576	6,795
California	168,397	307,652	446,933	476,697	800,714	1,134,456	1,883,450
Alabama							
Texas	178,276	236,837	453,253	956,683	1,014,945	1,405,077	2,073,823
Louisiana					858,145	1,747,379	2,119,948
Kentucky	380,176	424,271	485,192	456,293	407,689	522,455	509,846
Tennessee	300	350	350	300	300	375	600
Arkansas and Wyoming	126,582	164,930	226,925	301,151	295,858	309,816	269,421
Colorado							
Oklahoma	417,221	860,159	1,806,193	3,490,704	6,731,770	7,334,599	7,436,389
South Dakota	19,500	24,400	16,164	31,999	16,984	30,412	31,166
North Dakota	235	2,480	3,025	7,010	5,738		
Oregon	100	250	50	....	....	....	....
Iowa	....	93	50	40	70	120	120
Michigan	....	....	255	820	1,330	1,470	1,405
Total	54,222,399	54,640,374	63,206,941	70,756,158	74,127,534	84,563,957	87,846,677

The following table shows the production and consumption of natural gas in 1914 b7 States: From the U. S. Geological Survey.

Quantity and value of natural gas produced and consumed in the United States in 1912 and 1913, by States.

1914

State	Produced			Consumed		
	Quantity (M cubic feet)	Cents per M cubic feet	Value	Quantity (M cubic feet)	Cents per M cubic feet	Value
West Virginia	238,740,162	14.87	$35,515,329	95,147,247	7.71	$ 7,334,690
Pennsylvania	108,494,387	18.80	20,401,295	164,834,542	17.25	28,439,324
Ohio	68,270,174	21.48	14,667,790	138,388,914	21.63	29,936,642
Oklahoma	78,167,414	10.30	8,050,039	*a*55,544,105	7.61	4,226,318
Kansas	22,627,507	14.76	3,340,025	*b*45,250,816	15.83	7,163,746
California	17,828,928	16.33	2,910,784	17,828,928	16.33	2,910,784
New York	8,935,187	29.10	2,600,352	18,401,830	29.94	5,510,204
Texas	13,433,639	18.38	2,469,770	13,433,639	18.38	2,469,770
La., Ala	26,774,695	8.32	2,227,999	*c*26,774,695	8.32	2,227,999
Indiana	2,579,675	29.28	755,407	4,443,244	32.02	1,422,880
Kentucky	1,421,818	34.52	490,875	7,225,626	24.73	1,787,308
Illinois	3,547,841	12.32	437,275	*d*3,547,841	12.32	437,275
Ark., Colo., Wyo.	962,998	22.23	214,103	962,998	22.23	214,103
So. Dak., No. Dak.	60,781	44.78	27,220	60,781	44.78	27,220
Missouri	18,085	29.41	5,319	18,085	29.41	5,319
Michigan	2,042	70.61	1,442	2,042	70.61	1,442
Tennessee	1,200	25.00	300	1,200	25.00	300
Iowa	200	100.00	200	200	100.00	200
Total	591,866,733	15.90	$94,115,524	591,866,733	15.90	$94,115,524

a Includes some gas piped from Oklahoma and consumed in Missouri.
b Includes some gas piped from Kansas and consumed in Missouri.
c Includes some gas piped from Louisiana to Texas and from Louisiana to Arkansas.
d Includes some gas piped from Illinois and consumed in Indiana.

WELL RECORD.*

The following table gives the record of natural gas wells in 1913, by States:

State	Productive Dec. 31, 1912	Drilled in 1913			Abandoned in 1913	Productive Dec. 31, 1913
		Gas	Dry	Total		
Alabama	19	......	7	7	1	18
Arkansas	97	3	1	4	2	98
California	71	9	4	13	8	a72
Colorado	8	......	......	......	3	5
Illinois	453	60	119	179	58	455
Indiana	2,547	69	24	93	246	2,370
Iowa	6	......	......	......	......	6
Kansas	2,106	506	253	759	315	2,297
Kentucky	267	23	7	30	20	270
Louisiana	155	53	24	77	18	190
Michigan	19	......	......	......	1	a 18
Missouri	70	6	......	6	16	60
Montana	......	1	......	1	......	1
New York	1,736	200	54	254	56	1,880
North Dakota	24	......	......	......	7	a17
Ohio	5,163	408	235	643	358	5,213
Oklahoma	936	423	298	721	307	1,052
Pennsylvania	11,543	1,011	259	1,270	299	12,255
South Dakota	35	2	......	2	2	b 35
Tennessee	6	2	......	2	......	8
Texas	87	43	29	72	7	123
West Virginia	5,533	1,038	128	1,166	108	6,463
Wyoming	24	4	......	4	......	28
Total	30,905	3,861	1,442	5,303	1,832	32,934

a Includes some artesian wells from which gas is used. *b* Artesian wells from which gas is used.

* Hill B. The production of Natural Gas in 1913

ACREAGE CONTROLLED BY NATURAL GAS COMPANIES.*

The following table shows the number of acres of land held by natural gas companies in 1912 and 1913, and whether the acreage was owned in fee or leased:

State	1912				1913			
	In fee	Leased	Gas rights	Total	In fee	Leased	Gas rights	Total
Alabama	570	216,000	....	216,570	70	170,200	....	170,270
Arkansas	600	20,059	....	20,659	600	8,131	....	8,731
California	2,434	7,690	....	10,124	3,160	1,774	4,960	9,894
Colorado	....	195	....	195	1,080	35	....	1,115
Illinois	3,568	165,337	17,342	186,247	1,687	174,766	2,032	178,485
Indiana	120,020	173,979	8,692	302,691	117,141	177,436	1,758	296,335
Kansas	25,405	366,475	17,870	409,750	32,217	406,046	13,945	452,208
Kentucky	2,970	113,947	....	116,917	3,348	141,840	636	145,824
Louisiana	15,625	301,664	....	317,289	19,896	343,871	4,414	368,181
Missouri	4,077	1,660	....	5,737	1,403	....	....	1,403
New York	10,689	490,506	1,205	502,400	14,220	447,112	74,212	535,544
Ohio	14,834	1,711,552	29,781	1,756,167	20,026	1,393,073	102,463	1,515,562
Oklahoma	7,047	1,058,144	95,857	1,161,048	18,943	1,242,701	149,834	1,411,478
Pennsylvania	115,242	1,675,116	397,030	2,187,388	146,472	1,684,925	380,043	2,211,440
Tennessee	500	....	....	500	500	....	....	500
Texas	7,660	153,919	6,369	167,948	14,857	508,776	16,910	540,543
West Virginia	124,880	2,202,642	691,794	3,019,316	111,712	2,521,253	522,786	3,155,751
Wyoming	2,968	3,970	....	6,938	2,328	16,368	....	18,696
Total	459,089	8,682,855	1,265,940	10,407,884	509,660	9,238,307	1,273,993	11,021,960

* Hill B. The Production of Natural Gas in 1913.

Record of field activity and acreage in the Appalachian States in 1914.

State	In fee	Leased	Gas rights	Total	Prod. Dec. 31, 1913
New York	11,571	626,717	5,903	644,218	1,929
Pennsylvania	179,929	1,577,889	395,301	2,153,119	12,438
West Virginia	103,636	2,281,117	706,753	3,091,506	6,534
Ohio	21,385	1,249,532	90,861	1,361,778	3,308
Kentucky	5,594	160,968	636	167,198	274
Total	322,115	5,896,223	1,119,481	7,417,819	26,483

State	Drilled in 1914			Aband. 1914	Prod. Dec. 31, 1914
	Gas	Dry	Total		
New York	178	55	233	76	2,031
Pennsylvania	998	236	1,234	413	13,023
West Virginia	856	154	1,010	196	7,194
Ohio	686	257	943	321	5,673
Kentucky	10	1	11	8	276
Total	2728	703	431	1014	28,197

Fig. No. 4

PART TWO

Properties of Gases

DESCRIPTION OF VARIOUS GASES—THEIR PROPERTIES AND ANALYSES.

Air—Air is a mechanical mixture of oxygen and nitrogen, with about 1% by volume of argon. At 29.318 barometer and 60 deg. fahr., one cubic foot will weigh .07483 lb. and 1000 cubic feet will weigh 74.83 lb.

While the composition of air varies, the following is taken from *Bulletin U. S. Geological Survey No. 330.*

By Volume				By Weight		
N.	O.	Ar		N.	O.	Ar
78.122	20.941	0.937	—	75.539	23.024	1.437

Air expands 1/491.2 of its volume at 32 deg. fahr. for every increase of 1 deg. fahr., and its volume varies inversely as the pressure.

Hydrogen—Hydrogen Gas H_2 is colorless, odorless, non-poisonous, and the lightest substance known. Hydrogen in a commercial gas makes it lighter, increases the heating value, the amount of air required for combustion, and the heat loss in the products of combustion. It is very combustible, and uniting with oxygen, burns with a pale blue, nearly non-luminous flame, producing water in the form of water vapor. Hydrogen is always a desirable constituent on account of its high calorific power and its avidity for combustion. It will not stand much compression without danger of self-ignition. Its high heating value is 324 B. t. u. per cubic foot at 60 deg. fahr. and 29.33 inches of mercury.*

*This basis of measurement, 60 deg. fahr. and 29.33 inches of mercury (14.65 lb. absolute) is adhered to throughout unless otherwise stated.

Olefiant Gas—This is sometimes called ethylene, and is the main illuminating constituent of coal gas. It has a chemical formula of C_2H_4. It is evolved when oil or coal is heated. It has a very high calorific power, 1578 gross B. t. u. per cubic foot, and possesses fourteen times the luminosity of marsh gas. It is colorless, odorless, and burns with a highly luminous flame.

Methane—In natural gas the chief member of the marsh gas series is methane or marsh gas itself, having the formula CH_4, and a composition of 25.03% hydrogen and 74.97% carbon by weight. The name marsh gas comes from the fact that it is frequently produced by the decay of plants in swamps and the bottom of rivers. When pure it is a colorless, odorless gas, lighter than air and having a specific gravity of .559. Its gross heating value is 1003 B. t. u. per cubic foot at 60 deg. fahr. and 29.33 inches of mercury (14.65 pounds per square inch absolute.)

Ethane—Ethane C_2H_6, the next member of the marsh gas series, is sometimes found in considerable quantities in natural gas. It greatly resembles methane in its general properties, being a better fuel and burning with a slightly luminous flame, which makes it a better illuminant than methane. The heat value per cubic foot is 1754 B. t. u.

Ethane contains 79.96% of carbon and 20.04% of hydrogen by weight.

Carbonic Oxide—This is also known as carbon monoxide, CO, and is one of the most important constituents of producer gas. It is odorless, colorless, practically insoluble in water, very poisonous and burns with a distinctive pale blue flame. Its high or gross heating value is 322 B. t. u. per cu. ft.

Carbon Dioxide—It is called carbonic acid and carbonic anhydride, CO_2. It is colorless, odorless, soluble in water, non-combustible, and is formed by the combustion of carbon and oxygen at high temperature

Oxygen O_2—This is tasteless, odorless, invisible and slightly heavier than air. It exists in a free state in the atmosphere and in combination in the ocean. It forms about one-fifth of the former and eight-ninths of the latter.

Nitrogen N_2—This is a colorless, odorless, non-combustible gas and is always present in large quantity in gases produced by incomplete combustion. It forms four-fifths of the volume of air.

Hydrocarbons—The number of known hydrocarbons is nearly two hundred. The term is applied to all compounds consisting only of hydrogen and carbon. These compounds exist in gaseous, vaporous, liquid and solid states. Low temperatures are conducive to the formation of the easily condensed, tarry compounds, while with high temperatures, the yield of hydrogen and permanent gases is greatly increased.

Illuminants—In gas analysis part of the constituents are sometimes mentioned as illuminants, the term illuminant signifying a substance that makes the gas flame luminous, and olefiant gas is usually included with this.

Natural Gas—The principal constituent is marsh gas. The exact composition varies with the different districts.

Oil Gas—This gas is made from oil, generally by allowing the liquid to flow slowly, and in a thin, continuous stream, through a highly heated pipe or retort where the oil is vaporized. This usually evolves hydrogen, marsh gas, and olefiant gas mixed with vapor which will usually be condensed in the scrubbing apparatus.

Coal Gas—It is also called "bench" or "illuminating" gas. The former refers to the benches which hold the retort while the latter is dubious, since several other gases are distributed as illuminating gas. Coal gas is made by destruc-

COMMERCIAL GASES*

(By Wyer)

Name	H	CH_4	C_2H_4	N	CO	O	CO_2	B. t. u. in 1 Cu. Ft. Explosive Mixture	B. t. u. Cu. Ft.	O. Required for Combustion	Air for Combustion
Natural gas (Pittsburgh)	3.0	92.0	3.0	2.0	....	....	....	91.0	978.0	1.94	9.73
Oil Gas	32.0	48.0	16.5	3.0	....	0.5	....	93.0	846.0	1.61	8.07
Coal or bench gas	46.0	40.0	5.0	2.0	6.0	0.5	0.5	91.7	646.0	1.21	6.05
Coke-oven gas	50.0	36.0	4.0	2.0	6.0	0.5	1.5	91.0	603.0	1.12	5.60
Carbureted water gas	40.0	25.0	8.5	4.0	19.0	0.5	3.0	92.0	575.0	1.05	5.25
Water gas	48.0	2.0	....	5.5	38.0	0.5	6.0	88.0	295.0	0.47	2.35
Producer-gas from hard coal	20.0	....	....	49.5	25.0	0.5	5.0	68.0	144.0	0.22	1.12
Producer-gas from soft coal	10.0	3.0	0.5	58.0	23.0	0.5	5.0	65.5	144.0	0.24	1.20
Producer-gas from coke	10.0	....	....	56.0	29.0	0.5	4.5	63.0	125.0	0.19	0.98
Blast-furnace gas	1.0	....	....	60.0	27.5	....	11.5	....	91.0	1.43	.72

COMBUSTIBLE GAS MIXTURES*

(By Wyer)

Name of Gas	Explosive Mixture Air to 1 Volume Gas
Hydrogen	2.4
Carbon monoxide	2.4
Marsh gas	9.6
Olefiant gas	14.4
Acetylene	12.0
Coal gas	5.7

*Note—Producer Gas and Gas Producers by S. S. Wyer.

tive distillation of bituminous coal in externally heated air-tight retorts. The resulting gas is withdrawn by an exhauster and the residual coke is removed periodically.

Coke Oven Gas—This is a gas made in a by-product coke oven; that is, the gas, tar, and ammonia evolved by distilling coal in a closed oven are saved and used as a by-product. Its composition is quite similar to coal gas.

Water Gas—This is produced by the decomposition of steam acting on incandescent carbon. On account of the large amount of carbon monoxide present the gas is very poisonous.

Natural Gas Analysis—To treat this subject fully would require a volume in itself. Therefore we refer the reader to Hempel's *Gas Analysis*, or Stone's *Practical Testing of Gas and Gas Meters.*

In general the analysis of gas consists in absorbing the constituents one by one, in appropriate reagents, and measuring the decrease of volume caused by such absorption.

Certain substances, such as hydrogen and methane, cannot readily be treated in this manner, and these are determined by exploding with oxygen and determining the products of the explosion or the diminution in volume of the original mixture.

To Obtain Sample of Gas—The sample tube commonly used is a glass bulb 1¾ inches in diameter and 2¾ inches long, with the ends drawn out into capillary tubes, and terminating in two short ends ¼-inch in diameter. One end is connected to the gas supply by means of a piece of rubber tubing; the gas is turned on, and is lighted at the other end of the sample tube. If the flame is not over 1½ inches long there will be no danger of melting the glass, and the bulb may be purged of air by continuing the combustion for a reasonable period. As a rule, one-half to three-quarters of an hour will be ample. Great care should be used to close the ends of the glass bulb to prevent leakage or allow the air

to mix with the gas on the inside of the tube. The safest way to do this is with a blow pipe and a pair of pliers, melting the ends of the glass tubes and squeezing them shut, thus making a seal of glass.

In making the seal, turn the gas partly off until the flame is about 1/4-inch long; then, with the blowpipe, seal the capillary nearest the outlet. With the gas pressure still on, seal the capillary at the other end.

Great care should be used in packing the bulb for shipment or carrying. The tube if properly packed can be shipped by express to any laboratory for analysis.

Explosive Mixture with Gas from the Petrolia (Tex.) Field—Oxygen required to create an explosive mixture with natural gas from the Petrolia Field. Tests made by E. S. Merriam, Ph. D.

Assuming that the compositions of gas is as given, the quantities of oxygen and of air are as shown:

Constituents.		*Oxygen Required.*
Illuminants C_2H_4	0.3	0.9
Carbonic Oxide		0.0
Hydrogen	0.8	0.4
Marsh Gas	47.2	94.4
Ethane	12.5	43.75
Carbonic Acid	0.2	0.0
Oxygen	0.4	0.0
Nitrogen	38.6	0.0
	100.0	139.45

One hundred volumes of this gas would therefore require 139.45 volumes of pure oxygen for its complete combustion. There is however, according to the analysis 0.4% of oxygen in the gas, subtracting this there remains 139.05 as the necessary volume of oxygen, and since air contains 20.93% of oxygen, the amount of air needed to furnish 139.05 volumes of oxygen will be 665. From the analytical figures, therefore, one volume of gas will need about 6.7 volumes of air to give the most vigorous explosion.

Candle Power—A standard candle power is the illumination obtained from the flame of a spermaceti candle burning at the rate of two grains per minute. Sixteen candle power is the illumination given off from sixteen such candles. In making candle power tests, reliance must be placed on the human eyesight, which is variable and uncertain. Conditions of atmosphere and temperature affect the standard candle differently, so that the tests vary. In judging the quality of gas this standard is not as satisfactory as by the B.t. u. standard, which is a positive criterion of the quality of natural gas. This test for heat is scientific, mechanical and accurate.

British Thermal Units (B. t. u.)—The B. t. u. standard of determining the quality of natural gas is universally recognized by the natural gas fraternity.

British Heat Unit, or British Thermal Unit, indicates the heat necessary to raise the temperature of one pound of pure water at 39 deg. fahr. through one degree.

There are two methods employed to ascertain the B. t. u. of any gas. One is to use the calorimeter, and the other is to compute it from the gas analysis. In the latter case, it is necessary to have the B. t. u.'s of the different gases found in the analysis. These are given on page 87.

B. t. u.'s figured from candle power are valueless.

There are several calorimeters, namely, Hinman-Junker, Simmance-Abady, Sargent, Doherty, and the Boys. The Hinman-Junker calorimeter is fully described in the following pages.

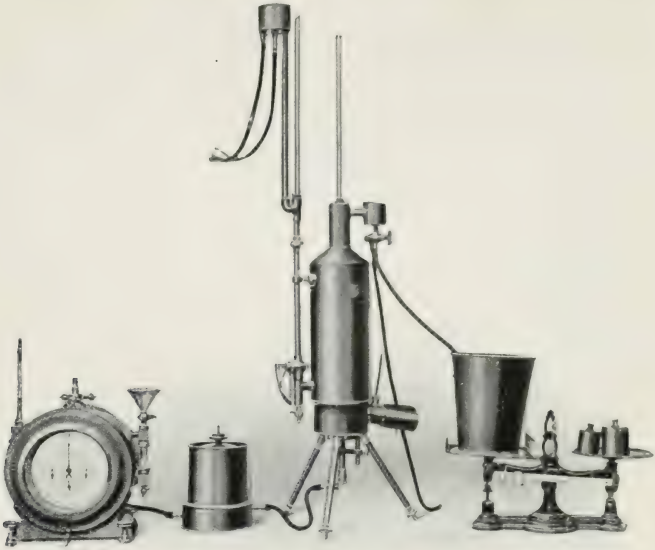


Fig. 5
THE HINMAN-JUNKER CALORIMETER
Used in Determining the B. t. u. of Either Artificial or Natural Gas

The Hinman-Junker Calorimeter—This apparatus is of the same general design and operates on the same principle as the well-known Junker Calorimeter, which has heretofore been regarded by gas experts as the most satisfactory form of calorimeter in use.

The complete apparatus consists of the one-tenth foot drum wet meter, wet governor, calorimeter with three thermometers, small graduate, rubber tubing, weighing balance, copper water buckets, or, in place of the last two items, a large graduate.

The 1/10 drum meter is a standard wet test meter, fitted with Hinman patent drum, water-line gauge glass, spirit levels, thumb screw feet, siphon pressure gauge and the

other customary fittings. The drum shaft is of German silver and all the sheet metal is tinned brass.

The wet governor is made of brass, nickeled. It supplies the calorimeter with gas at a perfectly uniform pressure. A set of weights is furnished with the governor.

The calorimeter is constructed on the same general lines as the Junker. The two water thermometers, however, are set on the same level, which is a great convenience in operating. On the outlet weir is a three-way cock which allows the water passing through the calorimeter to go either to the waste or to the weighing or measuring receptacle. The operation of the three-way cock is as follows: The water running through the calorimeter before and after the test goes to the waste. At the instant the meter hand comes to zero the key of the three-way cock is turned. When the desired amount of gas has passed through the meter the cock key is instantly turned back to allow the water to go to the waste. There is a vent tube on the cock to allow all the water to drain out of the tubing going to the weighing or measuring receptacle. By the use of this three-way cock the amount of water used during the test is accurately and easily measured.

The exhaust tube for the products of combustion has a damper, on the axis of which is a hand moving in a graduated arch. By this means the position of the damper is definitely known and it can be reset in subsequent tests. The burner is provided with a baffle screen and a mirror for observing the condition of the flame.

The weighing balance is sensitive to one-thousandth of a pound. It has steel knife edges and agate bearings. The 10 lb. set of brass weights consists of 4 lb., 2 lb., 1 lb., 5/10 lb., 2/10 lb., and 1/10 lb. weights. The scale on the beam is divided into one hundred parts, each part representing 1/1000 of one pound.

Two water buckets are furnished. These buckets are made of copper, tinned on the inside and polished on the outside. Their capacity is about 9 lb. each. When the bucket is placed on the scales, they are so arranged as to balance. If it is preferred to measure the water a graduate of the desired size can be furnished.

In accordance with recommendations made by the Committee on Gas Colorimetry of the American Gas Institute, calorimeters are furnished with baffle plates on the burner to prevent downward radiation from the gas flame.

Specific Gravity—Specific gravity is the ratio between the density of a body and the density of some other body chosen as a standard. The specific gravity of solids and liquids is given in terms of water. In this case the specific gravity is the ratio between the mass of any volume of the substance and the mass of an equal volume of water.

Fig. 6—SPECIFIC GRAVITY APPARATUS

In stating the specific gravities of gases, air or hydrogen are generally taken as standards.

Specific Gravity Apparatus—This is a very simple and convenient apparatus for ascertaining the specific gravity, or density, of gases. It consists of a glass jar with a metal top into which fits a brass column having suspended from its base a long graduated glass tube and at its top a cock and a ground joint socket, into which sets a socket holding a small glass tip closed in at the top with a very thin piece of platinum. In this platinum is a minute hole to permit the passage of gas or air at a very slow rate.

The mode of operation is as follows: The glass jar is filled with water to or a little above the top graduation of the tube. The tube is then withdrawn so as to fill it with air. The cock on the standard is then closed and the tube replaced in the jar. The cock is then opened and with a stop watch the time is taken that elapses while the water passes from the lowest graduation to the top or the next to the top graduation.

The tube is then withdrawn and filled with gas and the procedure repeated the same as with air, care being taken to use the same graduation in both cases.

The specific gravity, air being one, is obtained by dividing the gas time squared by the air time squared.

Formula is—

$$\text{Specific Gravity} = \frac{G^2}{A^2} = \left(\frac{G}{A}\right)^2$$

G = Time gas requires to pass through orifice.
A = Time air requires to pass through orifice.

While boring out the hole in the tip will shorten the time for each individual test it will also greatly increase the liability of error in the final results. The longer time it takes for each test, the more accurate the results.

Heating Value and Specific Gravity—When it is impossible to obtain a calorimetric determination of the heating value of a particular gas, the next best procedure is to compute it from the chemical analysis of the gas, using the values shown in the following table for the heating value of the constituent gases.

Multiply the percentage of each gas present by its corresponding heating value per cubic foot, and add the products.

The specific gravity is obtained in the same manner from the specific gravities and proportions of the constituent gases shown by the analysis.

Such computed results are necessarily subject to whatever errors there may be in the analysis of the gas, and unless this has been done with great care and precision, a wide dis-

crepancy may exist between the calculated and the actual values. The following B. t. u. values are gross or high values, and are based on one cubic foot of gas at 60 deg. fahr. and four ounce pressure, or 14.65 pounds per square inch absolute.

Kind of Gas	Symbol	Gross Heating Value B. t. u. per Cu. Ft.	Specific Gravity (Air=1)
Methane	CH_4	1003	0.5529
Ethane	C_2H_6	1754	1.0368
Ethylene	C_2H_4	1578	0.9676
Carbon monoxide	CO	322	0.9671
Hydrogen	H_2	324	0.0692
Hydrogen sulphide	H_2S	668	1.1769
Nitrogen	N_2	....	0.9701
Carbon dioxide	CO_2	..	1.5195
Helium	He	...	0.1382
Oxygen	O_2	....	1.1052

Illuminating Properties of Natural Gas—Natural gas in connection with the mantle of alkaline earth (cerium and thorium) has produced the cheapest and best illuminant. Where natural gas can be had at twenty five cents per thousand cubic feet and fifty candle power can be obtained from the consumption of two and one-half cubic feet per hour with a mantle, the cost of one candle power per hour is but 0.00125 of a cent.

In an ordinary argand burner with chimney, natural gas will give about twelve candle power with a consumption of five to six cubic feet per hour. If consumed in an ordinary tip, seven to eight cubic feet per hour will yield six candle power.

All natural gas has not the same illuminating value. In some districts it carries a small percentage of heavier hydrocarbons, which add much to its illuminating properties.

TESTS TO DETERMINE POISONOUS GASES IN NATURAL GAS FROM THE CADDO (LA.) FIELD

In presenting the following tests by Prof. E. S. Merriam it must be borne in mind that the results obtained do not establish the fact that all natural gas is harmless. The gas used in the tests was practically pure methane with no detectable quantities of higher hydro-carbons.

TESTS CONDUCTED ON THE NATURAL GAS SUPPLY OF LITTLE ROCK, ARKANSAS, AUGUST 7th, 1913.

By E. S. Merriam, Ph. D.

"The tests described below were made with the object of ascertaining whether the natural gas supplied to it's consumers, by the Little Rock Gas and Fuel Company, contained any poisonous constituents.

There is a widespread belief that many varieties of natural gas contain carbon monoxide. Work done in the Bureau of Mines makes it probable that carbon monoxide is never found in natural gas. It's reported presence in many analyses is due to the use of unsuitable methods of examination.

Two tests for carbon monoxide were made:—1st, when blood is exposed to an atmosphere containing carbon monoxide the gas is absorbed and a compound of carbon monoxide with the hemoglobin of the blood is formed, having a pink or purplish color quite different from the color due to oxyhemoglobin. The formation of this color is one of the most positive and conclusive tests we have for carbon monoxide.

A dilute solution of steer's blood in water was prepared (about 1 in 300). Three Nessler tubes were filled with this solution. On passing one liter of the city gas supply through the blood solution, in one of the tubes, no change in color

was noted. In order to show that carbon monoxide, if present in the gas, could be detected by this test, a mixture of city gas and carbon monoxide was prepared—10 cc of carbon monoxide was mixed with two liters of city gas making a 0.5% mixture. This mixture was bubbled through a Nessler tube containing blood; the color appeared after the passage of about a quarter of the quantity of the mixture.

The blood tube which had been previously treated with the city gas alone and had failed to give the reaction, gave it very readily when treated with the mixture of carbon monoxide and gas.

2nd: A dilute solution of palladium nitrate is reduced by carbon monoxide and also by hydrocarbons of the ethylene series, by hydrogen sulphide, and by free hydrogen. The metal appears in the form of very fine black particles floating about in the light yellow liquid. A thin smoky deposit of metal is also formed on the glass of the test tube near the surface of the liquid. These fine particles of palladium coalesce in a short time and appear in the bottom of the test tube as a black sediment.

On passing one liter of the city gas through 5cc of a solution of palladium nitrate, no change whatever could be noticed, even on comparing the solution with a blank of 5cc of the original solution. The above described mixture of carbon monoxide and gas gave the reaction unmistakably.

The failure to get a positive result from the city gas with this solution not only excludes carbon monoxide, but also eliminates free hydrogen, hydrocarbons of the ethylene series, and hydrogen sulphide.

A special test for hydrogen sulphide was further made by passing two liters of city gas through a U tube containing granular lead acetate. No sign of blackening could be detected. This is an extremely delicate test and minute traces would have made themselves evident.

Absorption experiments using bromine water and ammoniacal cuprous chloride in the ordinary Hempel form of apparatus failed to show any carbon monoxide or ethylene hydrocarbons. This method was employed because these are the customary reagents used in technical gas analysis, altho the tests by blood and palladium salts are far more decisive.

As a further test of a different sort, a canary bird was placed in a pasteboard box of the following dimensions:—17 x 23 x 24 inches; the capacity of the box was therefore 154 litres. Holes were bored for the admission of gas and provision was made for obtaining a sample of the atmosphere, within the box. A glass plate which could be pasted on was provided so that the bird could be observed. After introducing the cage with the bird and closing the glass door, forty litres of gas were introduced into the box. This would give an atmosphere within the box containing at the start about 35% of gas. The glass door was then pasted down air-tight, and the box was left undisturbed for one hour and six minutes. During this period the bird showed no signs of distress and was apparently as well as ever at the close of the test. At the end of the test a sample of the atmosphere within the box was obtained and showed the following result on analysis:—92.05 cc were taken and after treatment with KOH lost 0.2 cc. This represents 1.22% of carbon dioxide mostly formed by the bird's breathing. After removal of oxygen by alkaline pyrogallic acid there remained 74.15 cc. From these figures the percentage of air in the box is calculated to be 93.1, or the atmosphere of the box contained 6.9% of gas. A confirmatory and more accurate result obtained by combustion showed 7.35% of gas.

In order to determine the nature and amount of the combustible constituents of the gas it was burned in a form of apparatus devised by the Bureau of Mines. The gas was handled over mercury and burned with pure oxygen, by the use of a hot spiral of platinum wire. The percentage of

carbon dioxide, originally present in the gas, was previously determined and its presence allowed for in the calculations. The volume of carbon dioxide and the contraction, due to burning, were corrected for deviation from the true gas laws. The measuring burette had been previously calibrated and was provided with a compensating device to avoid errors due to changing temperature and pressure.

Below are the results of combustions:—

Oxygen taken	Gas taken	Volume after Burning	Volume after KOH	Corrected volume of CO_2	Corrected value of Contraction	Empirical formula of hydrocarbons present
97.35	42.85	55.8	13.4	41.95	84.3	$CH_{4.03}$

The gas is therefore almost wholly methane with a small amount of nitrogen and carbon dioxide. The gas can act physiologically only by diluting the atmospheric oxygen present.

Summarizing the above results we have:—

% Methane	97.8
% Carbon Dioxide	1.25
% Nitrogen	0.95
% Carbon Monoxide	0.00
% Olefines	0.00
% Hydrogen	0.00
% Hydrogen Sulphide	0.00
	100.00

PHYSIOLOGICAL TEST OF THE NATURAL GAS FROM CADDO (LA.) FIELD, AUGUST, 1913

By E. S. MERRIAM, PH. D.

"A chemical analysis performed August 7th, having shown the natural gas supply of Little Rock to consist almost wholly of methane, it was believed that a physiological test would furnish further and conclusive evidence that the gas does not possess toxic qualities.

Mr. B. J. Gifford consented to the use of the kitchen of his house at 2605 State Street for the test. This room measured 16 feet in length, 12 feet in width and 11 feet in height; its total capacity, therefore, was 2,112 cubic feet. The gas pipes were disconnected at the stove and hot water heater, in order to allow a free flow of gas into the room. Mr. W. F. Booth, Mr. B. J. Gifford and Prof. E. S Merriam remained in the room during the entire period of the test. Dr. J. H. Kinsworthy was admitted when the test had been under way for 31 minutes and he remained until the end.

A meter in the basement of the house allowed the total quantity of gas admitted to the room to be measured. The windows and doors of the room were tightened somewhat by stopping the cracks with newspaper. Prof. Merriam determined the percentage of oxygen in the air of the room at the beginning of the test, and at frequent intervals during the test; so that a close record of the amount of gas in the atmosphere of the room could be obtained at any moment.

The test was begun at 2:55 P.M., Mr. Booth, Mr. Gifford and Mr. Merriam being then in the room. The initial reading of the gas meter was 6300. At 3:31, the gas supply was turned off and the final reading of the meter was 6750, showing that 450 cubic feet of gas had entered the room during this interval of 36 minutes. The gas, therefore, came in at the rate of 12.5 cubic feet per minute. At 3:26, Dr. Kinsworthy was admitted to the room, 5 minutes before the gas supply was shut off. At 3:38 a bottle was filled with

water, the water poured out and the bottle tightly corked. In this way a sample of the atmosphere of the room at that moment, was secured. It was tested later. At 3:54 P. M., or 59 minutes after the start of the test, a second sample of the atmosphere of the room was obtained. At 4:00 P. M., the test was brought to a close by opening the doors and windows.

In spite of the fact that the day was uncomfortably warm, none of the persons undergoing the test felt the slightest discomfort; there was no headache, nausea, dizziness, nor any of the usual symptoms of gas poisoning, experienced by any of the four men, either during or after the test.

Below are recorded the observations made during the test:

Time P. M.	Percent. of Oxygen	Percent. of Air	Percent. of Gas	Remarks
2:55	20.6	100.0	0.0	Start of test.
3:00	20.1	97.6	2.4	....
3:05	19.6	95.2	4.8	....
3:15	18.7	90.8	9.2	....
3:26	17.9	86.9	13.1	Dr. Kingsworthy entered.
3:31	....	......	....	Gas turned off.
3:35	18.4	89.3	10.7	....
3:38	....	......	....	First sample of atmosphere taken.
3:41	18.8	91.25	8.75	....
3:49	19.0	92.25	7.75	....
3:54	19.05	94.6	5.4	Second sample of atmosphere taken.
4:00	....	......	....	End of test.

The sample of atmosphere obtained at 3:38 was tested by withdrawing the cork and applying a match. The gas ignited and burned quietly, flaring back into the bottle. The sample collected at the end of the test was tested in the same way, but did not burn or explode. This result was expected, as the Bureau of Mines has found that a mixture of air and

methane must contain 5.5% of methane to be explosive. The sample collected at 3:54 contained, according to the analysis, only 5.4% of natural gas, or methane, and could not, therefore, be expected to explode.

From the analytical results it is evident that from about 3:10 to 3:50 there was gas enough in the atmosphere of the room to form an explosive mixture.

Two other important points are to be noted from the analytical figures.

First, the rate of escape of gas from the room after the supply was shut off is quite rapid, the percentage of gas falling from 13.1 to 5.4 in 28 minutes. This was in a room where all the doors and windows were closed and the cracks stopped up. In an ordinary room it seems extremely unlikely that sufficient gas could accumulate to reduce the oxygen percentage to a dangerous degree.

Second, the gas was introduced into the room at the rate of 12.5 cubic feet per minute; the room was of an average size, but the percentage of oxygen was reduced to only 17.9; even with all the burners of a stove turned on full and all gas jets open, gas could not be introduced at a higher rate than two cubic feet per minute.

This test shows, therefore, that no ill effects whatever can be attributed to an atmosphere containing unburned Little Rock Natural Gas. Four men observed no effect whatever from breathing an atmosphere containing far more gas than is ever likely to result from accidental causes."

HEAT FACTS

By Albert A. Summerville, Ph. D.

"Heat travels at the same speed as light, namely, 186,000 miles per second. It travels in straight lines and may pass through a medium without heating it. This is proven by the fact that although the sun heats by radiation, the upper layers of air are always cold.

Steam or hot water radiators will give off more radiant heat in proportion to the polish of their surfaces. In other words a silvered or gilded radiator will give off less heat than a dull black surfaced one.

The thermos bottle keeps its contents at nearly the same temperature as when placed in the bottle because of the lack of radiation. In addition to a vacuum chamber surrounding the bottle, which is a non-conductor of heat, the outside is silvered, further preventing radiation.

A rug feels warmer than a tiled floor, because the rug is a poorer conductor of heat."

Radiation of Heat—Radiation of heat takes place between bodies at all distances apart, and follows the law for radiation of light.

Heat rays proceed in straight lines and the intensity of the rays radiated from any one source varies inversely as the square of their distance from the source.

GAS ANALYSIS FROM VARIOUS GAS FIELDS

State and District	Constituents: Methane or marsh gas CH_4	Constituents: Ethane C_2H_6	Constituents: Carbon dioxide CO_2	Constituents: Nitrogen, N	Constituents: Oxygen, O	Constituents: Other constituents	Specific gravity	B. t. u. per cubic foot	Analyst	Where published	Remarks
	%	%	%	%	%						
ALABAMA											
Fayette Co.:											
Fayette......	98.30	....	0.30	1.30	0.10	....	......	......	G. A. Burrell	U. S. Geol. Survey, Mineral Resources 1911	Collected by D. T. Day, July, 1910.
ARKANSAS											
Sebastian Co.:											
Fort Smith..	96.12	.....	.93	2.71	0.13	Hydrogen 0.01 Carbon monoxide 0.08 Olefines 0.02	.....	966	....	....	....
do ..	92.40	.....	.42	3.38	.30	H 2.70 CO .50 C_2H_4 .30	.....	923	H. E. Manning..	....	Analysis made Oct. 1905.
CALIFORNIA											
Coaling No. 1..	79.0	.....	19.2	1.8	....	....	.746	667	....	A.S.M.E., Aug., 1912.	1911.
Sunset No. 2...	87.5	.....	7.7	3.6	0.7	Trace of H_2	.643	......	....	A. S. M. E., Aug., 1912.	1911.

Ventura Co.: Torrey	54.2	35.6	6.8	3.4	....	....	.805	1,240	G. A. Burrell	A. S. M. E., Aug., 1912 Bu. of Mines	Collected by B. B. Grinnell, Feb., 1910.
Fresno Co.: Coalinga Field	88.00	....	11.10	.90	....	....	......	937	G. A. Burrell	Bu. of Mines, Bulletin 19	Collected by G. H. Salisbury. June, 1910.
Kern River Field	84.30	8.00	6.50	1.20	....	....	......	1,047	G. A. Burrell	Bu. of Mines, Bulletin 19	Collected by C. Ballah, Nov., 1909.
Santa Barbara County: Santa Maria Field	62.70	20.20	15.50	1.40	.20	....	......	1,044	G. A. Burrell	Bu. of Mines, Bulletin 19	Collected by I. C. Allen, Aug., 1909.
ILLINOIS Pike County: Pittsfield	73.81	....	0.81	21.92	3.46	....	......	......	....	Ill. Geol. Surv.	....
Bureau Co.: Princeton	13.97	....	0.10	85.83	0.05	Carbon monoxide .05	......	......	....	Univer. Geol. Surv. of Kan.	1907.
INDIANA Grant Co.: Marion	77.4	14.18	.73	6.66	....	Olefines .86 Helium .167	.659	1,025	Cady & McFarland	University Geol. Survey of Kan.	Collected by B. A. Kinney, Aug., 1906.
Howard Co.: Kokomo	93.6	....	.40	6.00	....	....	......	......	F. C. Phillips	Am. Chem. Jour., 1894.	Collected by E. C. Somers.
Madison Co.: Anderson	93.07	.49	.26	3.02	.42	H 1.86 HS .15 CO .73	......	......	Prof. H. C. Howard.	U. S. Geol. Surv., Ann. Rept., 1889	....

GAS ANALYSIS FROM VARIOUS GAS FIELDS—Continued

State and District	Constituents: Methane or marsh gas CH_4	Ethane C_2H_6	Carbon dioxide CO_2	Nitrogen N	Oxygen O	Other constituents	Specific gravity	B. t. u. per cubic foot	Analyst	Where published	Remarks
	%	%	%	%	%						
KANSAS.											
Dexter	14.33	1.06	.....	82.87	.10	Helium 1.64	.897	162	Cady & McFarland	Univer. Geol. Survey	1906. Depth 850 feet, press. 200 lb., July, 1906.
Chanute	94.7	.....	.....	4.96	.10	Helium .24	.573	950			
Allen Co.: Iola	89.66	.....	.90	7.76	.45	CO 1.23	.....	.....	E. H. S. Bailey.	U. S. Geol. Survey, 1896.	.....
Anderson Co.: Garnett	94.30	.36	.20	4.61	.....	HE .37 C_2H_4 .16	.....	.....	Cady & McFarland.	Am. Chem. So. Journal.	Depth 610 feet, Press. 200 lb., Aug., 1906.
Chautauqua Co. Peru	81.70	7.6	.51	9.39	.10	HE .19 C_2H_4 .51	.....	.....	Cady & McFarland.	Am. Chem. So.	July, 1906.
KENTUCKY Martin Co. Ky. Mingo Co.,	75.14	23.16	Trace	1.59	0.11	.....	.677	1,231	H. H. Craver Chemist	.....	Jan., 1914 Pittsburgh Test. Labor'y.
LOUISIANA Caddo Field	95.	.....	2.43	2.56	.....	Sulphide .01	.....	980	.....	.....	.....

Jennings	88.4	1.03	1.8	5.76	1.81	Olefins .8 Carb. mon. .4 Helium, tr.	......	......	....	University Geol. Survey, of Kans.	1907.
MISSOURI Kansas City ...	87.20	7.03	.60	3.65	.10	CO .20 He .01 C_2H_4 1.20 Other .01	......	......	Cady & McFarland.	Am. Chem. Soc. Journal.	Depth 300 ft., Press. very low.
NEW YORK Baldwinsville	98.4	.....	0.25	0.40	Trace	H Trace Monoxide 0.95	.558	1,013	Dr. Durand Woodman.	....	1899.
Ontario Co.: W. Bloomfield	82.41	2.94	10.11	4.31	.23	....	.693	.....	Prof. Wurtz	Am. Inst. of Mining, vol. 13	1870.
N. DAKOTA Bottineau Co.: Westhope ...	82.70	0.20	.....	12.40	3.00	H 0.50 CO 1.20	......	......	E. J. Babcock	U. S. Geol. Survey, 1911.	Press. 55 to 60 lb.
OHIO Auglaize Co.: St. Marys ...	93.85	.20	0.23	2.98	.35	H 1.74 H_2S .21 CO .44	......	......	Prof. C. C. Howard.	U.S. Geol. Survey Min. Resources, 1890	Trenton Limestone
Hancock Co.: Findlay	93.35	.35	.25	3.41	.39	H 1.64 H_2S .20 CO .41	......	......	do	do	....
OKLAHOMA Kay Co.: Blackwell ...	83.40	10.31	.....	5.19	....	Olefins .61 Hydrogen .33 Helium .16	.624	1,018	Cady & M'Farland	Am. Chem. So. Jour., vol. 29 p. 1530.	Pressure 185 lb.
Glen Pool ...	49.1	44.1	6.1	.7	....	....	.768	1,271	G. A. Burrell	Bu. of Mines, 1913.	......
Stevens Co.: Duncan ..	96.20	....	.20	2.40	.60	CO .40 Ethylene .20	......	1,025	Gulick Henderson	....	Oct., 1913.

GAS ANALYSIS FROM VARIOUS GAS FIELDS—Continued

State and District	Constituents: Metoane or marsh gas CH_4	Ethane C_2H_6	Carbon dioxide CO_2	Nitrogen N	Oxygen. O	Other constituents	Specific gravity	B. t.u. per cubic foot	Analyst	Where published	Remarks
	%	%	%	%	%						
OREGON Tillamook. . .	2.00	. . . . .	.15	97.85	. . . .	. . . .	. . . . . .	. . . . . .	G. A. Burrell	. . . .	Collected by G.A.Macready Sept., 1910.
PENNSYLVANIA Butler.	.70	16.75	. . . . .	12.38	.05	Olefins .4 Hydrogen .27 Helium .15	.685	1,082	Cady & Mcfarland	. . . .	. . . .
Clarion Co.:	85.11	13.64	. . . . .	1.25	Trace	. . . .	.625	1,170	Pittsburgh Test. Lab.	. . . .	Mar. 3, 1915.
Washingt'nCo.: McDonald. . .	. . . . .	. . . . .	. . . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . .
PA. AND W. VA. Pittsburg. . . .	81.59	17.76	. . . . .	.65	Trace	. . . .	.665	1,199	Pittsburgh Test. Lab.	. . . .	Jan. 1, 1914.
SOUTH DAKOTA Hughes Co.: Pierre.	86.5	. . . . .	1.35	11.86	. . . .	Olefins .29	. . . . . .	8.68	Cady & Mcfarland	Univer. Geol'l Sur. of Kans.	. . . .

TENNESSEE											
Memphis....	90.36	.....	3.13	3.83	.83	H 1.85	......	......	G. A. Burrell	....	Dec., 1911.
TEXAS											
Clay Co.:	47.2	12.5	.....	38.6	.4	Illum. .3 Hydrogen .8 Car. acid .2	.76	748	....	....	1912.
ShackelfordCo.											
Moran.......	80.80	.....	.....	19.2	....	....	......	835.5	S.H.Worrell	Tex. Univ. Bul.	1913.
UTAH											
Near Salt Lake City.........	22.3	37.8	0.8	19.7	0.9	Ethylene 0.7 Carb. mon. 1.2 Hydrogen 16.6	......	944	J. T. Kingsbury	Univ. Geol. Survey of Kan.	1894.
WEST VIRGINIA											
Blue Creek ..	76.06	23.15	.....	.79	Trace	....	.694	1,240	Pittsburgh Test. Lab..	....	May 14, 1914.
Brooke Co.:											
Follansbee...	.....	21.8	.....	.50	....	C_3H_8 77.7	1,390	2,468	G. A. Burrell	Bur. of Mines, Paper No. 10, 1912.	....
Doddridge, Harrison and Lewis Co's:..	80.50	18.00	.....	1.50	Trace	....	.653	1,192.2	H.H. Craver	....	....
Parsons	83.40	15.40	.....	.30	....	CO .15 Illum. .50	.64	1,025	....	Unpublished...	1905.
CANADA											
Pt.Albino, Ont.	96.57	.....	Trace	2.69	....	Hydrogen Sulphide .74	.62	974	Francis C. Phillips....	Am. Chem. Journ., 1894.	1894.
Vancouver, Al.	93.56	.....	0.14	6.3	....	....	.58	938	do	do	....

Analysis of Gas taken at different times from the city mains at Taft, California. First analysis is from so-called dry gas or from wells that produce gas only.

Carbon dioxide	.60	3.50
Illuminants	.20	.45
Oxygen	.20	.15
Methane	92.05	93.43
Ethane	3.15	1.15
Nitrogen	3.80	1.32
	100.00	100.00
Specific gravity	58.08	60.21
Gross B. t. u., at 60 fahr., 29.92″	1021	1098
Net " "	927	1018

Following is an analysis of wet gas, or gas produced in connection with oil:

Carbon dioxide	8.2
Illuminants	2.0
Oxygen	0.3
Carbon monoxide	1.1
Methane	76.1
Ethane	12.3
Nitrogen	0.0
	100.0
Specific gravity	74.6
Gross B. t. u	1084

EUROPEAN GAS

Location	Methane	Carbon Dioxide	Nitrogen	Olefins	Carbon Monoxide	Hydrogen	Oxygen	Hydrogen Sulphide	Total
Charlemont, Staffordshire, England	99.6	0.3	0.1	....	....	....	....	....	100.00
Peninsula of Apscheron, (Baku) So. Russia (*C. Schmidt*)	92.49	0.93	2.13	4.11	....	0.34	....	....	100.00
Peninsula of Apscheron, (Baku) So. Russia (*C. Schmidt*)	93.09	2.18	0.49	3.26	....	0.98	....	....	100.00
Peninsulas of Kertsch and Tamen (*R. Bunsen*):									
Titarovka Erdolberg	92.24	3.50	....	4.26	....	....	....	....	100.00
Jenikale Gas Springs	95.39	4.61	....	....	....	....	....	....	100.00
Boulganak Mud Volcano	97.51	2.49	....	....	....	....	....	....	100.00
Selonnaiagora Central Crater	95.56	4.44	....	....	....	....	....	....	100.00
Jenikale Gas Springs	97 09	2.11	....	....	....	....	....	....	100.00

GASES FROM RIVERS, LAKES, MARSHES, ETC. (*By Maumeme*)

Name of Gas	River Visle, Rheims, France		Marsh-gas at Marburg Botanical Gardens		Santa Venerina, Sicily		Girgente, Sicily	Val-Corrente, Sicily	Paterno, Sicily
	Present	Jan. 26, 1850			Old	Fresh			
Methane	48.4	42.5	47.37	76.61	83.6	95.5	90.4	*32.5	5.0
Ethane	....	....	.....	.....	....	....	....	....	....
Ethylene	6.3	6.6	.....	.....	....	....	....	....	....
Carbon dioxide	18.0	8.5	3.10	5.36	4.2	3.1	1.2	67.0	90.7
Carbon monoxide	14.2	21.8	.....	.....	....	....	....	....	....
Oxygen	0.3	0.4	0.17	....	....	1.2	1.7	0.5	1.0
Hydrogen	10.0	18.3	.....	.....	....	....	....	....	....
Nitrogen	2.8	1.9	49.36	18.03	12.2	....	6.7	....	3.3
Hydrogen sulphide	....	....	....	...	....	0.2	....	0.2	....
	100.0	100.0	100.0	100.00	100.0	100.0	100.0	100.0	100.0

*With nitrogen.

GASES FROM GERMAN SPRINGS

(By Robt. Bunsen)

Name of Gas	Gases from Aachen Hot Springs						Gases diffused in Nenndorf sulphur water		
	Gas from Kaiser-quelle. Free gas	Gas diffused in water at Kaiser-quelle	Gas from Cor-nelius quelle. Free gas	Gas diffused in water at Cornelius quelle	Quirinus bad	Rosen-quelle	Trink-quelle	Quelle unter dem Gewalbe	Bade-quelle
Nitrogen	66.98	9.00	81.68	7.79	6.41	9.14	17.30	19.91	23.91
Carbon dioxide	30.89	89.40	17.60	92.21	93.25	90.31	69.38	68.29	72.63
Hydrogen sulphide	0.31	.....	.....	.....	.....	.....	11.86	11.72	3.29
Hydrogen	.....	.....	.....	.....	.....	.....	.....	.....	.....
Carbon monoxide	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oxygen	.....	1.23	.....	.....	0.08	.....	.....	.....	.....
Marsh-gas	1.82	0.37	0.72	.....	0.26	0.55	1.46	0.28	0.17
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

GASES FROM VOLCANOES AND GEYSERS

FUMAROLE GASES FROM ICELAND. *(By Bunsen)*

Name of Gas	1	2	3
	Fumaroles from great Hecla crater		Fumaroles from lava stream of 1845
Nitrogen	81.81	82.58	78.90
Oxygen	14.21	16.86	20.09
Carbon dioxide	2.44	0.56	1.01
Hydrogen sulphide	0.00	0.00	0.00
Sulphur dioxide	1.54	0.00	0.00
Carbon monoxide	0.00	0.00	0.00
Hydrocarbons	0.00	0.00	0.00
Hydrochloric acid	Undetermined		
	100.00	100.00	100.00

GASES FROM CLEFTS IN LAVA OF VESUVIUS

Name of Gas	1	2	3	3a
Sulphur dioxide	0.64	.....	0.03	0.07
Oxygen	20.00	20.70	20.50	20.77
Nitrogen	78.36	79.30	79.47	79.16
	99.00	100.00	100.00	100.00

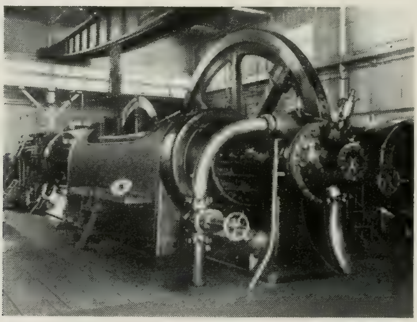


Fig. 7

PART THREE

Field Work

A VERY COMPLETE SECTION DEALING IN DETAIL WITH EVERY PHASE OF LEASE, DERRICK, DRILLING, SHOOTING AND CARE OF GAS WELLS.

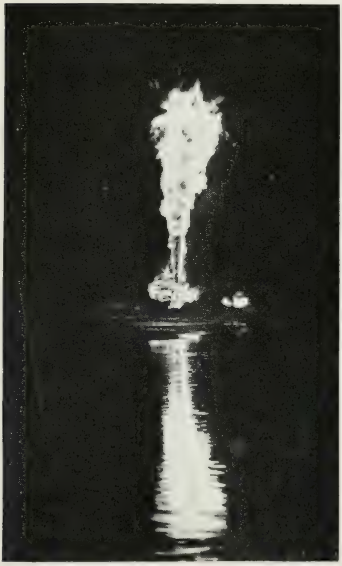


Fig. 8—A BURNING GAS WELL IN CIMARRON RIVER BED
Cushing Field (Okla.)

Lease—Almost the entire amount of gas and oil produced in the world is obtained from leased lands. The lease, therefore, which embodies in legal form the consideration, penalties and agreements between the land owner and the operator, is of fundamental importance, and should be a matter of record in the Recorder's office of the county in which the property is located. Leases of property owned or controlled by the Indians are under Federal supervision through the Department of Interior.

A lease may be obtained on a straight yearly rental basis, or, more commonly, on a basis of a specified amount for each gas well drilled in which gas in paying quantities is found. Likewise in event of finding oil in paying quantities

In Consideration of One Dollar to me in hand paid by The Alden natural Gas and Fuel Company the receipt of which is acknowledged, and of the benefits that may accrue to me as hereinafter stated I Robert Douglas of the Town of Alden Erie County, New York, do hereby give, grant and release to said first party, for and during the term of ten years from date, and as much longer as gas or oil shall be found in paying quantities, or as the rental is paid thereon, the exclusive right, license and privilege of drilling and sinking wells for oil or gas, and taking and removing said product therefrom, the right to dig and use water wells therefor, the exclusive right to lay pipes and mains and to conduct said product through the same and a right of way for the purpose hereof, upon, in, through, and over the following described premises.

All that tract of land situate in the town of Alden County of Erie New York, described and bounded as follows, to wit

North by ~~lands of~~ the Highway

South by lands of Ehreman

East by lands of Ellen S. Brunett and Walter Brunett

West by lands of H. S. Armstrong

Containing 4 acres of land, more or less, upon the following terms and conditions:

First:—That if, within ~~five~~ one years from date, a well has not been drilled on said premises, said lessee shall pay me 1.00 Dollars per annum thereafter ~~until work is commenced.~~ payable in advance

Second:—That, in case gas in paying quantities is found, said lessee shall pay me for wells producing ~~500~~ 300 M cubic feet per day, or more, $100 per annum, and for smaller wells in same proportion, for each well so long as it is opperated by removing gas into the mains. rental for well must be paid as soon as gas is removed into the mains

Third.—*THAT IF OIL IS FOUND, I AM TO HAVE ONE EIGHTH OF THE PRODUCTION, DELIVERED FREE OF CHARGE INTO TANKS OR PIPE LINES.* Tankage furnished free by company, or the cash value thereof if I prefer

Fourth:—That, in the locating of a well on said premises I am to be consulted as to its location.

Fifth:—That no well shall be drilled within two hundred feet of a house or barn, or in any orchard, on said premises without my consent

Sixth:—That all crops damaged by entering said premises for drilling shall be paid for at the rate of $50.00 per acre for the amount actually damaged or destroyed. All pipes must be laid at least 18 inches under the ground if I desired

Seventh:—That said lessee may at any time remove all casings, pipe and property put upon and used on above described premises.

The grants and conditions hereof shall bind the parties hereto, their heirs, executors, administrators and assigns. Failure of the lessee to comply with the conditions hereof or to make the payments specified, will render this lease null and void and not binding upon either party; and said lessee may, by surrendering this lease, terminate it at any time and thereby cancel all obligations, hereunder, either expressed or implied

WITNESS my hand and seal this 7 day of Oct. 1901

Robert Douglas — Seal.

Witness, A Bohner — Seal.

Fig. 9—FORM OF GAS LEASE

the land owner generally receives a royalty of one eighth or one sixteenth of the total amount of oil produced from the property during the life of the wells.

In the lease the operator is generally given the exclusive right to drill for oil or gas, and a right of way for pipe line across the land.

Some leases stipulate that the farmer or land owner is to receive free gas for house use on the lease, but it is better that the operator install a domestic meter and require the land-owner to pay a reasonable price for the gas above a certain amount per month or per year. Leases granting free gas to the landowner have fallen into disfavor owing to the many abuses of the privilege and it is now the common custom to exclude the clause granting free gas privileges.

Well Contract—The well contract is an agreement between the operator and the drilling contractor.

The contract is generally based on a certain price per foot of completed hole. In some cases the operator furnishes gas for fuel, in which case the contract should stipulate that the drilling contractor must use a boiler regulator to prevent extravagant waste of gas.

Well Location—In locating a well, consideration should be given to the water supply for the boiler, and to placing the boiler on the windward side of the derrick with reference to prevailing winds. In anticipating a large gasser, just prior to drilling in, the boiler should be moved to a safe distance.

Derrick or Rig—There is a great variety of gas well drilling derricks or rigs, but all of them can be placed in two classes—standard and portable. Under the standard are the bolted steel or wood and the nailed derrick. Steel derricks are not commonly used on account of their weight in moving and the difficulty of replacing new parts at distant

points in the field. The bolted derrick (wooden) is more expensive in the beginning but there is less waste in tearing down and putting up. A bolted wooden derrick should be painted and the bolts kept well oiled. The nailed derrick is the same style as the wooden bolted derrick except that the legs, girts and braces are spiked together in erecting.

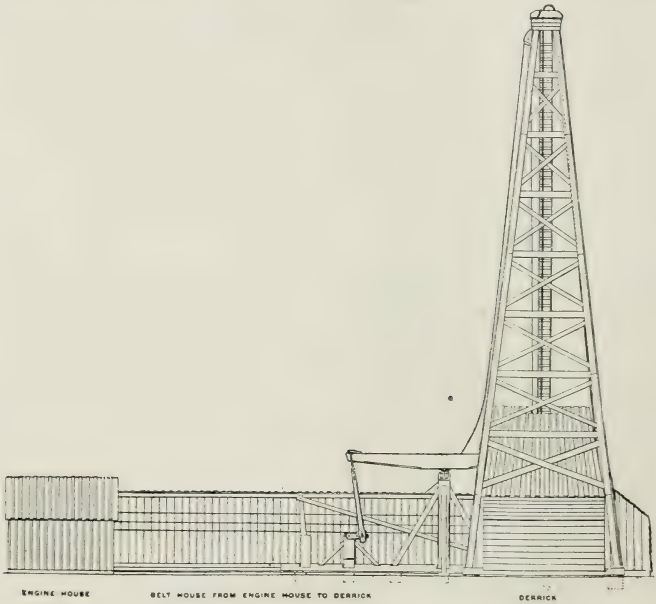


Fig. 10—CLOSED RIG

The lower part of the derrick is enclosed to protect the machinery and workmen from cold or stormy weather.

The average cost of tearing down and erecting a wooden derrick by a rig builder is $75.00 without the hauling. A portable derrick has been used to drill a well 3000 feet deep but they are most commonly used in drilling wells less than 1000 feet deep. The height of a standard derrick is from 74 feet to 84 feet.

Fig. 11—STEEL DERRICK

DERRICK AND DRILLING OUTFIT

1 Nose Sill
2 Mud Sills
3 Mud Sills
4 Main Sill
5 Sub Sill
6 Sand Reel Sill
7 Bumper, Engine Block to Main Sill
8 Engine Block
9 Engine Mud Sills
10 Derrick Mud Sills
11 Derrick Floor Sills
12 Foundation Posts
13 Bull Wheel Posts
14 Bull Wheel Shaft
15 Bull Wheel, Brake Side
16 Bull Wheel, Tug Side
17 Calf Wheel Posts
18 Calf Wheel Shaft
19 Calf Wheel
20 Skeleton Rim for Calf Wheel
21 Sand Reel Reach
22 Band Wheel Shaft
23 Iron Tug Wheel for Calf Wheel
24 Back Jack Post Box
25 Tug Pulley
26 Band Wheel
27 Front Jack Post Box and Cap
28 Shaft, Crank, Wrist Pin and Flanges
29 Iron Sand Reel
30 Sand Reel Posts
31 Jack Post
32 Pitman
33 Sand Reel Lever
34 Sampson Post
35 Sampson Post Braces
36 Derrick Crane Post
37 Headache Post
38 Walking Beam
39 Jack Post Brace
40 Derrick Ladder
41 Derrick Cornice
42 Derrick Girts
43 Derrick Braces
44 Bull Wheel Cants
45 Bull Wheel Arms

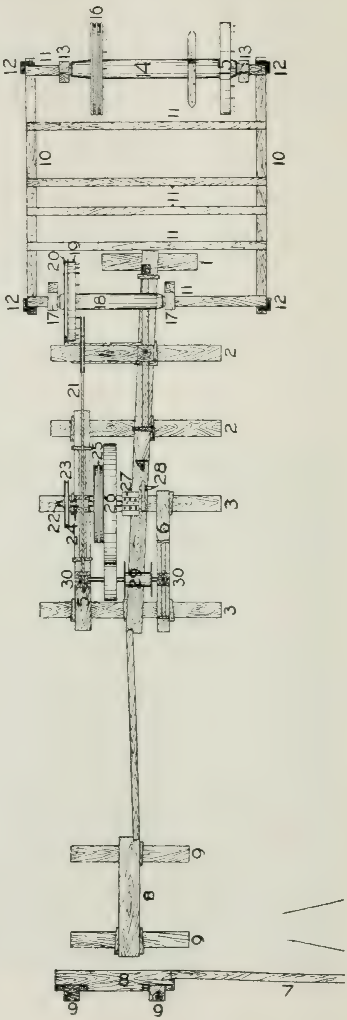


Fig. 12

WITH ALL PARTS NUMBERED

46 Calf Wheel Cants
47 Calf Wheel Arms
48 Belt
49 Adjuster Board
50 Derrick Floor
51 Bull Wheel Post Brace
52 Crown Pulley
53 Sand Pump Pulley
54 Casing Pulley
55 Sand Line
56 Drilling Cable
57 Casing Line
58 Bull Rope
59 Calf Rope
60 Temper Screw Elevator Rope
61 Temper Screw Pulleys
62 Center Irons
63 Stirrup
64 Calf Wheel Gudgeons (not Visible)
65 Bull Wheel Gudgeons (not Visible)
66 Brake Band for Bull Wheel
67 Brake Lever for Bull Wheel
68 Brake Staple for Bull Wheel
69 Sand Reel Hand Lever
70 Brake Lever and Staple for Calf Wheel
71 Brake Band for Calf Wheel
72 Telegraph Wheel
73 Derrick Crane with Chain Hoist and Swivel Wrench
75 Crown Block
76 Temper Screw
77 Rope Socket
78 Jars
79 Stem
80 Bit
81 Bailer or Sand Pump

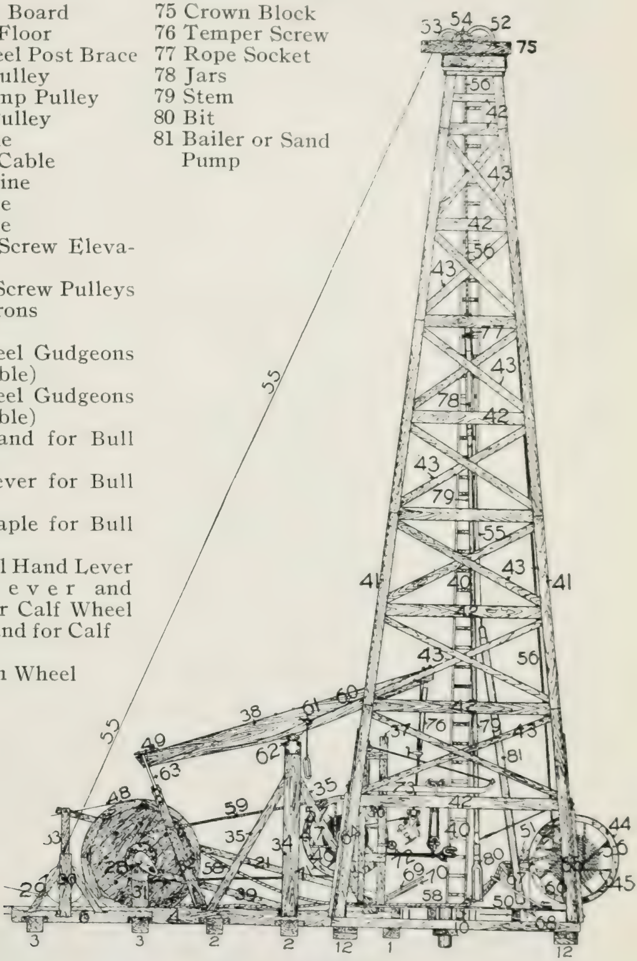


Fig. 13—(Continued)
NOTE: Boiler and engine are not shown on this diagram

SPECIFICATIONS OF MATERIAL REQUIRED TO BUILD A COMPLETE DOUBLE-TUG STANDARD RIG.

NUMBERS REFER TO DRAWING ON PAGES 112 AND 113

Derrick 80 Feet High

No. in Diagram	No. of Pieces	NAME OF PART *Timbers: Oak, Beech or Maple*	Size in Inches	Length in Feet
4	1	Main Sill	18x18	32
2	2	Mud Sills	16x16	16
3	2	Mud Sills	16x16	20
1	1	Nose Sill	16x16	8
5	1	Sub Sill	16x16	18
9	2	Engine Mud Sills	16x16	14
..	2	Engine Pony Sills	12x14	12
8	2	Engine Blocks	8x20	10
6	1	Sand Reel Sill	12x14	12
10–11	8	Derrick Sills	9x10	21
7	1	Bumper (engine to mudsills)	6x 8	24
..	1	Derrick Blocking	16x16	16
..	1	Dump Block	12x12	8
34	1	Sampson Post	16x16	16
31	1	Jack Post	16x16	12
39	2	Jack Post Braces	6x 8	16
35	4	Sampson Post Braces	6x 8	14
37	1	Headache Post	6x 8	16
13	2	Bull Wheel Posts	12x14	10
51	1	Bull Wheel Posts Brace	6x 8	14
17	1	Calf Wheel Post	12x14	10
30	1	Sand Reel Post	12x14	6
38	1	Walking Beam	14x24	26
..	3	Keys	3x 5	16
75	1	Crown Block	5x14	14
27	1	Jack Post Cap	5x14	5
30	1	Knuckle Post	5x14	8
33	1	Sand Reel Lever	9x11	10
32	1	Pitman Tapered	5x5–5x12	12
75	2	Sand Pulley Block	2x12	20
..	2	Bull Wheel Spools	2x 6	20
..	2	Bull Wheel Spools	2x 4	16
69	1	Sand Reel Handle	2x 8	8
14	1	Octagon Bull Wheel Shaft	18x18 16x16	14
18	1	Octagon Calf Wheel Shaft	18x18 16x16	9

SPECIFICATIONS—DOUBLE-TUG RIG *(Continued)*

No. in Diagram	No. of Pieces	NAME OF PART *Pine or Hemlock*	Size in Inches	Length in Feet
41	30	Derrick Legs, etc.	2x 8	16
41	22	Derrick Legs, etc.	2x10	16
..	6	Doublers	2x10	20
..	6	Starting Legs	2x 8	18
42	4	First Girts	2x12	18
42	4	Second Girts	2x10	18
43	8	First Braces	2x 6	20
43	14	Second Braces, etc.	2x 6	18
..	30	Floor and Walk	2x12	20
40	20	Ladders and Stringers	2x 4	16
..	8	Engine House Stringer	2x 4	12
26	72	Band Wheel and Girts	1x12	16
43	60	Braces	1x 6	16
..	..	4000 Feet Boards	1	16
..	..	1000 Feet Boards	1	14
..	28	If Rig is to be Full Doubled	2x 8	16
..	12	If Rig is to be Doubled Front and Rear only	2x 8	16

Outfit of Rig and Calf Irons, as follows:

FOUNDRY IRONS

Diagram No.	
28	1 Shaft, Crank, Wrist Pin and Collar.
28	1 Pair Flanges with Keys and Bolts.
62	1 Set Center Irons with Bolts.
52	1 Crown Pulley.
53	1 Sand Line Pulley.
63	1 Walking Beam Stirrup.
65	1 Pair Bull Wheel Gudgeons with Bands and Bolts.
24	1 Jack Post Box.
20	1 90-inch Skeleton Rim for Calf Wheel.
23	1 Iron Tug Wheel for Calf Wheel.
64	1 16-inch Bowl Calf Wheel Gudgeon with Band and Bolts.
64	1 30-inch Flange Calf Wheel Gudgeon with Band and Bolts.
54	2 Casing Pulleys.

BRAKE IRONS

Diagram No.	
66	1 Brake Band for Bull Wheel
67	1 Brake Lever for Bull Wheel
68	1 Brake Staple for Bull Wheel
	1 Back Brake for Sand Reel if Wood Reel.
71	1 Brake Band for Calf Wheel
70	1 Brake Lever for Calf Wheel
70	1 Brake Staple for Calf Wheel

SPECIFICATIONS—DOUBLE-TUG RIG *(Continued)*

WOODWORK

Diagram No.		Diagram No.	
26	1 Set Band Wheel Cants.	46-47	1 Set Calf Wheel Cants, Arms and Handles.
25	1 Set Double Tug Pulley Cants.		
44-45	1 Set Double Tug Bull Wheel Cants, Arms and Handles.		

SAND REEL

Diagram No.	
29	1 Wood Sand Reel or 1 Iron Sand Reel with Lever and Straps.

NAILS, BOLTS AND WASHERS

150 pounds 10d Nails.
150 pounds 20d Nails.
150 pounds 30d Nails.
4 ¾x8-inch Machine Bolts.
8 ¾x9-inch Machine Bolts.
3 ¾x10-inch Machine Bolts.
10 ¾x12-inch Machine Bolts.
4 ¾x14-inch Machine Bolts.
4 ¾x16-inch Machine Bolts.
11 ¾x18-inch Machine Bolts.
6 ¾x20-inch Machine Bolts.
2 ¾x22-inch Machine Bolts.
4 ⅞x12-inch D. E. Bolts with 2-inch Square Nuts.
6 ⅞x22-inch D. E. Bolts with 2-inch Square Nuts.
58 ¾-inch Wrought Iron Washers
58 ¾-inch Cast Iron Washers.
10 ⅞-inch Cast Iron Washers.
1 piece 1½-inch Pipe 18 inches long.

NOTE—The above Bolts and Washers are in addition to those furnished with the Foundry Rig Irons.

Estimated shipping weight of complete specifications as shown on this and two preceding pages, including rig irons and lumber, 78,000 pounds.

SPECIFICATIONS OF MATERIAL REQUIRED TO BUILD A CALIFORNIA RIG

Derrick 82 Feet High with 20 Foot Base, Using Standard Rig Irons

No. of Pieces	NAME OF PART *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
1	Walking Beam	12x12x12x26	26	676
1	Engine Block	22x22	9	363
1	Main Sill	16x16	30	640
1	Sub-Sill	16x16	20	427
1	Sampson Post	16x16	16	341
1	Select Bull Wheel Shaft	16x16	14	299
1	Select Calf Wheel Shaft	16x16	6	128
4	Mud Sills	14x14	16	1045
1	Tail Sill and Post	14x14	16	261
1	Nose Sill and Jack Post Cap	14x14	16	261
2	Engine Mud Sills	14x14	14	458
2	Casing Sills	14x14	12	392
1	Jack Post	14x14	12	196
1	Back Brake and Blocking	12x12	20	240
2	Bull Wheel and Calf Wheel Post	12x10	24	480
1	Bumper	10x12	14	140
2	Pony Sills	10x12	12	240
2	Side Sills	8x8	22	234
11	Derrick Sills, Casing Rack and Blocking	8x8	20	1177
1	Bunting Pole	6x6	26	78
1	Dead Man	6x6	20	60
2	Jack Post Braces	6x6	18	108
1	Calf Wheel Brace	6x6	16	48
5	Back Brake, Headache Post Sampson Post and Bull Wheel Braces	6x6	14	210
5	Calf Wheel and Short Braces	4x6	16	160
2	Select Crown Blocks	5x16	16	214
1	Knuckle Post	5x16	12	80
2	Pitman and Swing Lever	5x5x5x14	12	140
14	Band Wheel (surface 1 side)	2x12	20	560
54	Derrick Foundation Floor, Walk and Girts	2x12	20	2160
8	Derrick Foundation and Girts	2x12	18	288
8	Girts and Top of Derrick	2x12	16	256
4	Girts	2x12	14	112
6	Starting Legs and Belt House Sills	2x10	26	258
28	Doublers	2x10	24	1120
20	Derrick Legs and to cut up	2x10	16	540

SPECIFICATIONS—CALIFORNIA RIG *(Continued)*

No. of Pieces	Name of Part *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
12	Derrick Roof, Forge and Belt House..............	2x8	18	288
4	Starting Legs............	2x8	18	96
20	Derrick Legs and to cut up	2x8	16	420
1	Bunting Pole to Jack Post	2x8	24	32
5	Belt House................	2x6	26	130
17	Braces.....................	2x6	20	340
8	Braces.....................	2x6	18	144
12	Braces and to cut up......	2x6	16	192
2	Engine House.............	2x6	14	28
3	Engine House.............	2x6	12	36
20	Ladders and to cut up.....	2x4	16	220
3	Engine House.............	2x4	14	27
3	Engine House.............	2x4	12	24
30	Boarding up..............	1x12	20	600
75	Boarding up..............	1x12	18	1350
146	Girts and Boarding up....	1x12	16	2336
50	Engine House Siding and Boarding up............	1x12	14	700
60	Boarding up..............	1x12	12	720
60	Braces and Ladders Strips	1x6	16	480
	Total Oregon Pine...	....	....	22,553
	Hardwood			
1	Oak Top of Crown Block..	4x5	16	27
1	Oak Top of Crown Block..	4x5	14	23
1	Oak Top of Beam and Dog	2x12	16	32
	Total Hardwood.....	....	....	82

CANTS—SINGLE TUG

56 1x8-inch Plain for 10-foot Band Wheel.

8 2½x8-inch Grooved for 8-foot Bull Wheel.

8 2½x8-inch Plain for 8-foot Bull Wheel.

72 1x8-inch Plain for 8-foot Bull Wheel.

8 2½x8-inch Plain for 7½-foot Calf Wheel.

40 1x8-inch Plain for 7½-foot Calf Wheel.

8 2½x8-inch Plain for 7-foot Tug Pulley.

8 2½x8-inch Grooved for 7-foot Tug Pulley.

16 1x8-inch Plain for 7-foot Tug Pulley.

32 lineal feet 1½-inch O.P. Round B. W. Handles.

1 Hardwood Follower.

24 O. P. Rig Keys.

SPECIFICATIONS—CALIFORNIA RIG *(Continued)*

NAILS, BOLTS, WASHERS, ETC.

50 pounds 60d Nails.
100 pounds 40d Nails.
100 pounds 30d Nails.
100 pounds 20d Nails.
150 pounds 10d Nails.
2 ¾x38-inch Bolts.
2 ¾x32-inch Bolts.
1 ¾x30-inch Bolts.
1 ¾x24-inch Bolts.
2 ¾x22-inch Bolts.
4 ¾x20-inch Bolts.
12 ¾x18-inch Bolts.
20 ¾x16-inch Bolts.
16 ¾x14-inch Bolts.
14 ¾x12-inch Bolts.
8 ¾x10-inch Bolts.
5 ¾x8-inch Bolts.
4 ¾x26-inch D. E. Bolts.
1 piece 1½-inch Round Iron 16 inches long.
6 1½-inch Cast Iron Washers.
20 1-inch Cast Iron Washers.
25 1-inch Wrought Iron Washers.
125 ¾-inch Cast Iron Washers.
100 ¾-inchWrought IronWashers
1 600-foot Coil Guy Wire.

RIG IRONS

1 Complete Set Rig and Calf Wheel Irons.

BRAKE IRONS

1 Complete Set Bull Wheel and Calf Wheel Brake Irons.

SAND REEL

1 Single or Double Drum Sand Reel with Cast Iron or Steel Flanges with Lever.

SPECIFICATIONS OF MATERIAL REQUIRED TO BUILD A CALIFORNIA COMBINATION STANDARD AND ROTARY RIG

Derrick 102 Feet High with 22 Foot Base, Using Standard Rig Irons.

No. of Pieces	NAME OF PART *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
4	Mud Sills	16x16	16	1365
2	Mud Sills	16x16	20	853
1	Sampson Post	16x16	16	341
1	Jack Post	16x16	16	341
1	Tail Sill	16x16	16	341
1	Sub Sill	16x16	20	427
1	Main Sill	16x16	32	683
1	Nose Sill and Back Brake	14x14	16	261
2	Pony Sills	14x14	12	392
2	Engine Blocks	22x22	9	726
1	Walking Beam	14x14x30	26	910
1	Calf Wheel Post	12x12	26	312
1	Bull Wheel Post	12x12	22	264
2	Jack Sills	14x14	22	719

SPECIFICATIONS—COMBINATION STANDARD AND ROTARY RIG (*Continued*)

No. of Pieces	Name of Part *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
1	Top Derrick	12x12	13	156
1	Bunting Pole	6x8	30	120
1	Headache Post	6x8	16	64
1	Back Brake Sill	6x8	10	40
2	Sampson Posts	6x6	16	96
4	Braces	4x6	20	160
6	Braces	4x6	16	192
4	Braces	4x6	14	112
4	Arms, Surface 4 sides	3x12	18	216
2	Arms, Surface 4 sides	3x12	16	96
22	Band Wheel, Surface 1 side	2x12	16	704
9	Band Wheel, Surface 1 side	2x12	22	396
9	Band Wheel, Surface 1 side	2x12	20	360
3	Derrick	2x8	24	96
1	Pitman	6x6x16	14	112
1	Swing Lever	6x6x16	12	96
2	Belt House	2x6	26	52
2	Belt House	2x6	24	48
2	Belt House	2x6	22	44
10	Braces	2x6	20	200
3	Engine House	2x6	14	42
2	Engine House	2x6	12	24
4	Engine House	2x4	12	32
20	Derrick	1x8	16	213
30	Belt House	1x8	20	400
50	Engine House and Derrick	1x12	16	800
35	Engine House and Derrick	1x12	14	490
90	Belt House	1x12	20	1800
12	Belt House	1x12	24	288
2	Derrick	12x12	24	576
7	Derrick	10x10	22	1283
4	Derrick	8x8	20	427
4	Derrick	2x10	26	173
4	Derrick	2x10	18	120
63	Derrick	2x10	16	1680
4	Derrick	2x12	24	192
4	Derrick	2x12	22	176
4	Derrick	2x12	20	160
4	Derrick	2x12	18	144
8	Derrick	2x12	16	256
8	Derrick	2x12	14	224

SPECIFICATIONS—COMBINATION STANDARD AND ROTARY RIG (*Continued*)

No. of Pieces	NAME OF PART *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
8	Derrick	2x12	12	192
10	Derrick	2x12	10	200
7	Derrick	2x6	24	168
8	Derrick	2x6	22	176
8	Derrick	2x6	20	160
16	Derrick	2x6	18	288
8	Derrick	2x6	16	128
18	Derrick	2x8	16	384
16	Derrick	2x8	14	299
4	Doublers	2x12	18	144
2	Doublers	2x12	20	80
56	Doublers	2x12	22	2464
4	B. W. Arms S. 4 S.	2½x10	18	150
2	C. W. Arms S. 4 S.	2½x12	16	80
4	Band Wheel S. 1 S.	2x12	18	144
4	Sway Braces	2x12	22	176
4	Sway Braces	2x12	20	160
4	Sway Braces	2x12	18	144
4	Sway Braces	2x12	16	128
4	Sway Braces	2x12	14	112
8	Sway Braces	2x10	28	373
16	Sway Braces	2x10	26	693
8	Sway Braces	2x10	24	320
8	Sway Braces	2x10	22	293
	Total Oregon Pine, feet			28,251
	Redwood			
16	Corners	3x12	20	960
	Hardwood			
1	Bull Wheel Shaft, Oak	16x16	14	299
1	Calf Wheel Shaft, Oak	16x16	6	128
2	Crown Block, Oak	6x6	12	72
1	Crown Block, Oak	6x6	6	18
1	Crown Block, Oak	2x12	6	12
1	Crown Block, Oak	6x16	16	128
2	Crown Block and Post	6x16	14	224
	Total Hardwood, feet			881

SPECIFICATIONS—COMBINATION STANDARD AND ROTARY RIG *(Continued)*

NAILS, BOLTS, WASHERS, ETC.

100 pounds 60d Nails.
200 pounds 30d Nails.
200 pounds 20d Nails.
200 pounds 10d Nails.
2 ¾x10-inch Bolts.
22 ¾x12-inch Bolts.
10 ¾x14-inch Bolts.
20 ¾x16-inch Bolts.
45 ¾x18-inch Bolts.
6 ¾x20-inch Bolts.
2 ¾x24-inch Bolts.
2 ¾x28-inch Bolts.
3 ¾x30-inch Bolts.
2 ¾x42-inch Bolts.
168 ¾-inch Cast Iron Washers.
18 1-inch Cast Iron Washers.
84 ¾-inch Wrought Iron Washers.
24 1-inch Wrought Iron Washers.
1 600-foot Coil ⅜-inch Guy Wire.

CANTS—SINGLE AND DOUBLE TUG

For specifications of cants see specifications for regular and heavy California rigs on preceding page.

RIG IRONS

One Complete Set Rig and Calf Wheel Irons.

BRAKE IRONS

1 Complete Set Bull Wheel and Calf Wheel Brake Wheel.

1 Single or Double Drum Sand Reel with Cast Iron or Steel Flanges with Lever.

Fig. 14—MOVING A DRILLING BOILER WITH OXEN IN BLUE CREEK FIELD (W. VA.)

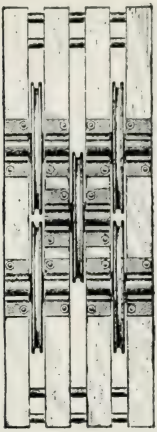
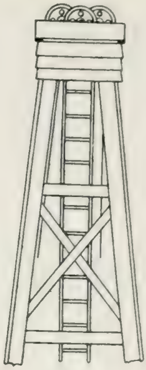


Fig. 15—STEEL CROWN BLOCK

Weight, 1200 lbs.



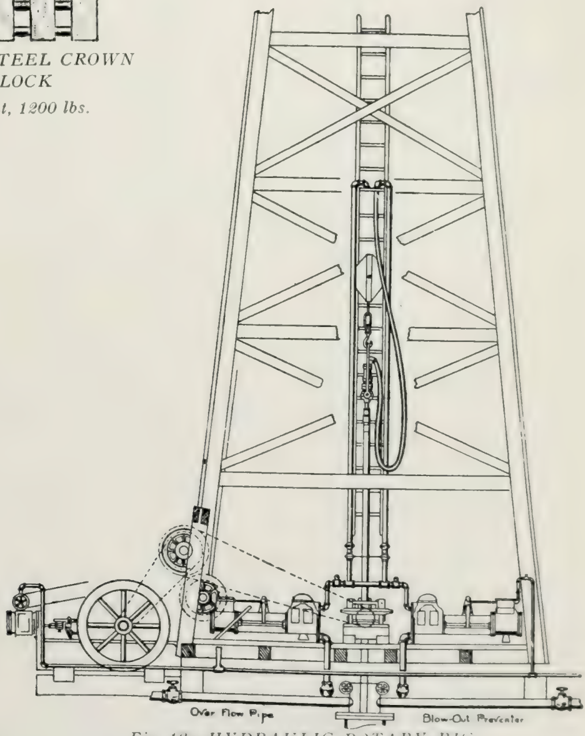


Fig. 16—HYDRAULIC ROTARY RIG

SPECIFICATIONS OF MATERIAL REQUIRED TO BUILD A CALIFORNIA HEAVY RIG

Derrick 82 Feet High with 20 Foot Base, Using Ideal Rig Irons

No. of Pieces	NAME OF PART *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
1	Select Beam	14x14x14x30	26	910
1	Engine Block	22x24	9	396
1	Main Sill	16x16	30	640
1	Sub Sill	16x16	20	427
1	Sampson Post	16x16	16	341
1	Jack Post	16x16	14	299
1	Select Bull Wheel Shaft	16x16	14	299
6	Rig and Engine Mud Sills	14x14	16	1566
1	Tail Sill and Post	14x14	16	261
1	Blocking	14x14	20	327
2	Casing Sills	14x14	14	458
3	Pony Sills and Nose Sill	14x14	12	588
2	Bull and Calf Wheel Posts	12x12	24	576
1	Back Brake and Blocking	12x12	20	240
1	Bumper	12x12	14	168
1	Bunting Pole	8x8	26	139
2	Side Sills	8x8	22	234
11	Derrick Sills and Casing Rack and Blocking	8x8	20	1177
2	Dead Men	6x6	20	120
2	Jack Post Braces	6x6	18	108
1	Calf Wheel Brace	6x6	16	48
5	Back Brake, Headache Post, Sampson Post and Bull Wheel Braces	6x6	14	210
5	Calf Wheel and Short Braces	4x6	16	160
2	Select Crown Blocks	6x16	16	256
1	Knuckle Post	5x16	12	80
1	Select Pitman	6x6x6x16	12	96
1	Select Swing Lever	5x5x5x14	12	70
4	Select S. 4 S. to 2½x11-inch Bull Wheel Arms	3x12	18	216
2	Select S. 4 S. to 2½x11-inch Calf Wheel Arms	3x12	16	96
14	S. 1 S. Band Wheel	2x12	20	560
54	Derrick Foundation Floor, Walk and Girts	2x12	20	2160
8	Derrick Foundation and Girts	2x12	18	288
8	Girts and Top of Derrick	2x12	16	256

SPECIFICATIONS—CALIFORNIA HEAVY RIG (*Cont.*)

No. of Pieces	Name of Part *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
4	Girts	2x12	14	112
28	Doublers	2x12	24	1344
6	Starting Legs and Belt House Sills	2x10	26	258
4	Short Starting Legs	2x10	18	120
48	Derrick Legs and to cut up	2x10	16	1296
1	Bunting Pole to Jack Post	2x8	24	32
12	Derrick Roof, Forge and Belt House	2x8	18	288
5	Belt House	2x6	26	130
17	Braces	2x6	20	340
8	Braces	2x6	18	144
12	Braces and to cut up	2x6	16	192
2	Engine House	2x6	14	28
3	Engine House	2x6	12	36
20	Ladders and to cut up	2x4	16	220
3	Engine House	2x4	14	27
3	Engine House	2x4	12	24
30	Boarding up	1x12	20	600
75	Boarding up	1x12	18	1350
146	Girts and Boarding up	1x12	16	2336
50	Engine House Siding, Derrick Roof and Boarding up	1x12	14	700
60	Boarding up	1x12	12	720
60	Braces and Ladder Strips	1x6	16	480
	Total Oregon Pine			24,547
	Hardwood			
1	Oak Calf Wheel Shaft	16x16	6	128
1	Oak Top of Crown Block	5x6	16	40
1	Oak Top of Crown Block	5x6	14	35
1	Oak Top of Beams and Dog	2x12	16	32
	Total Hardwood			235
	**Oregon Pine*			
4	Girts	2x12	18	144
4	Girts	2x12	16	128
4	Girts	2x12	14	112
2	Girts	2x12	20	80
8	Braces	2x8	22	235
8	Braces	2x8	20	213
8	Braces	2x8	18	192
8	Braces	2x8	16	171
	Total			1,275

*Note—If outside girts and braces are wanted, add the following.

CANTS—DOUBLE TUGS

56 1x8-inch Plain for 10-foot Band Wheel.
16 2½x8-inch Grooved for 8-foot Bull Wheel.
8 2½x8-inch Plain for 8-foot Bull Wheel.
80 1x8-inch Plain for 8-foot Bull Wheel.
8 2½x8-inch Plain for 7½-foot Calf Wheel.
40 1x8-inch Plain for 7½-foot Calf Wheel.
24 O. P. Rig Keys.
16 2½x8-inch Grooved for 7-foot Tug Pulley.
8 2½x8-inch Plain for 7-foot Tug Pulley.
24 1x8-inch Plain for 7-foot Tug Pulley.
32 lineal feet 1½-inch O. P. Round B. W. Handles.
1 Hardwood Follower.

NAILS, BOLTS, WASHERS, ETC.

50 pounds 60d Nails.
100 pounds 40d Nails.
100 pounds 30d Nails.
100 pounds 20d Nails.
150 pounds 10d Nails.
2 ¾x42-inch Bolts.
2 ¾x32-inch Bolts.
1 ¾x30-inch Bolt.
1 ¾x30-inch Bolt.
1 ¾x26-inch Bolt.
1 ¾x24-inch Bolt.
2 ¾x22-inch Bolts.
4 ¾x20-inch Bolts.
26 ¾x18-inch Bolts.
12 ¾x16-inch Bolts.
10 ¾x14-inch Bolts.
25 ¾x12-inch Bolts.
1 ¾x10-inch Bolt.
2 ¾x8-inch Bolts.
4 ⅞x28-inch D. E. Bolts.
1 piece 1½-inch Round Iron, 16 inches long.
2 1½-inch Cast Iron Washers.
20 1-inch Cast Iron Washers.
25 1-inch Wrought Iron Washers.
130 ¾-inch Cast Iron Washers.
100 ¾-inch Wrought Iron Washers.
1 600-foot Coil Guy Wire.

IDEAL RIG IRONS

1 Complete Set 5- or 6-inch Ideal Rig and Sprocket Calf Wheel Irons.

BRAKE IRONS

1 Set Bull Wheel and Calf Wheel Brake Irons.

SAND REEL

1 Double Drum Sand Reel with Steel Flanges with Lever.

SPECIFICATIONS OF MATERIAL REQUIRED TO BUILD A CALIFORNIA ROTARY RIG

Derrick 106 Feet High with 24 Foot Base

No. of Pieces	Name of Part *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
1	Engine Block	22x24	9	396
2	Mud Sills	14x14	16	522
2	Pony Sills	14x14	12	392
1	Blocking	14x14	20	327
2	Casing Sills	14x14	24	784
1	Blocking	12x12	20	240
1	Bumper	12x12	14	168
2	Side Sills	10x10	26	434
8	Derrick Sills	8x8	24	1024
4	Casing Sills and Blocking	8x8	20	428
2	Dead Men	6x6	20	120
6	Pump Foundation	6x6	18	324
2	Select Crown Block	6x16	16	96
72	Floor Girts and Doublers	2x12	24	3456
8	Girts	2x12	22	352
4	Girts	2x12	20	160
8	Girts	2x12	18	288
4	Girts	2x12	16	128
23	Derrick Foundation and Top	2x12	20	920
12	Derrick Foundation	2x12	18	432
4	Starting Legs	2x10	26	172
4	Starting Legs	2x10	18	120
54	Derrick Legs	2x10	16	1458
4	Top of Derrick	2x10	18	120
8	First Set Braces	2x8	24	256
8	Second Set Braces	2x8	22	232
8	Third Set Braces	2x8	20	216
8	Fourth Set Braces	2x6	20	160
8	Fifth Set Braces	2x6	18	144
8	Sixth Set Braces	2x6	16	128
30	Ladders and to cut up	2x4	16	330
50	Boarding up	1x12	24	1200
75	Boarding up	1x12	20	1500
50	Boarding up	1x12	16	800
70	Braces and Ladder Strips	1x6	16	560
	Total Oregon Pine			18.387
	Hardwood			
1	Oak Top of Crown Block	5x6	16	40
1	Oak Top of Crown Block	5x6	14	35
	Total Hardwood			75

NAILS, ETC.—100 pounds 40d Nails, 100 pounds 30d Nails, 100 pounds 20d Nails, 100 pounds 10d Nails, 2—600-foot Coils Guy Wire.

Fig. 17—POLE TOOL RIG (CANADIAN)

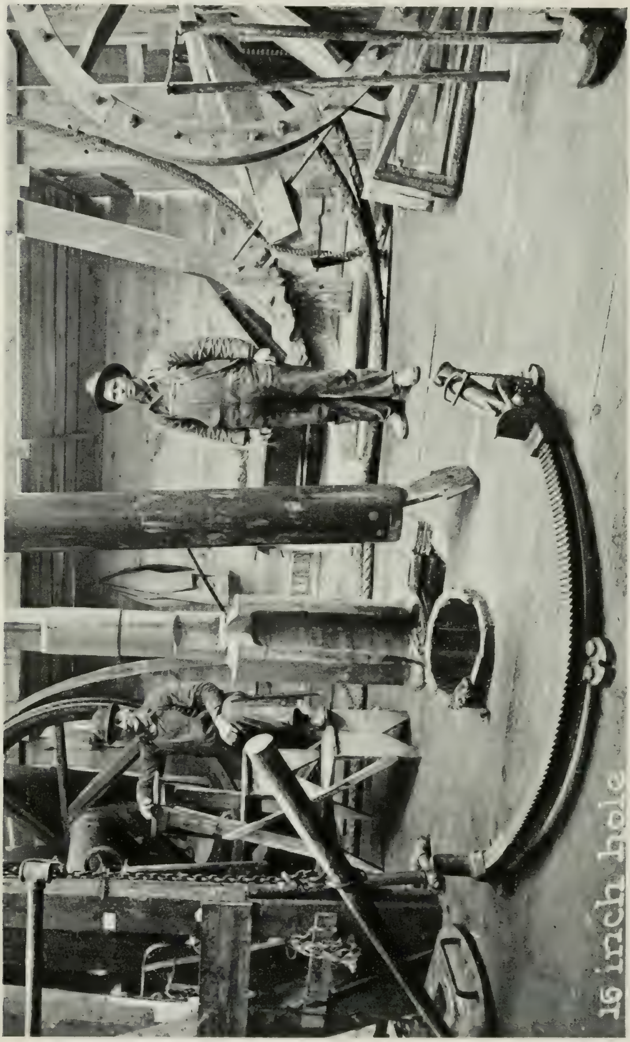
Bull Wheel—The bull wheel is the large wheel on the derrick floor on which is coiled the manila or wire line used in drilling.

The first American saw mills used the wheel to haul logs out of the water to the saw. It was first known as the "pull wheel," but from its strength the word was changed to "bull wheel".

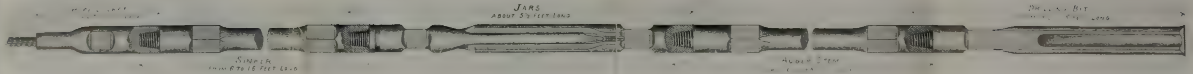
Bull Rope—The "Bull Rope" acts as a belt between the band wheel and the "bull wheel". It probably takes its name from the "bull wheel". It is generally made from a piece of the drilling cable of a two or two and one-half inch manila rope.

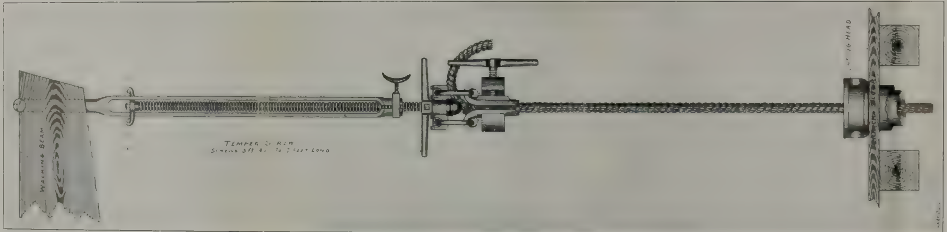
Walking Beam—The walking beam is as old as prehistoric times. It was originally the "working beam " but the name was changed to "walking beam," probably through the peculiar motion resembling walking. It was used by the Egyptians and was known as "Shadoof," a device for raising water from the Nile for irrigation purposes. In this country it is familiarly known as the "well sweep." The first steamships used it and called it the "walking beam."

Fig. 18—MIDWAY FIELD, KERN COUNTY, CALIFORNIA


16 inch hole

COMPLETE "STRING" OF DRILLING TOOLS





The well must be sunk by "spudding" to a depth admitting the tools some distance below the derrick floor before the walking beam and temper screw can be brought into action.

A "string" of drilling tools is the term used by drillers in describing the tools attached to the cable and employed in the actual drilling process. The illustration shows a complete "string." This may be varied to suit conditions or circumstances. The sinker bar is seldom used, and in some cases the jars are not required. The proper time for effecting these variations can be determined only by expert drillers.

Drilling—Wells vary in depth from 200 feet to 7000 feet. Very shallow wells are from two to sixteen inches in diameter. Deep gas wells start with a ten inch hole, or larger, depending on the formation, and finish with a hole from four and seven-eighths inches to six and one-quarter inches in diameter. The hole is reduced in size from time to time as the drill proceeds, each reduction being after the casing is put in, after which the well is allowed to stand long enough to determine whether the hole has been cased dry or not.

The casing should extend beyond the flow of water. Often a steel shoe is used on the bottom of dry pipe or casing. This makes the casing tight at the bottom and less apt to leak, but on the other hand, it is harder to pull the casing afterward.

In event of the casing leaking after being set, wheat or rice can be put in on the outside of the casing and oftentimes will stop the leakage. Where there is no water directly beneath the gas vein, the well should be drilled about 25 feet deeper, thus forming a pocket for the accumulation of sand and cave-ins.

Where there is water underneath the gas sand and the sand is shallow, do not drill over one screw into the sand. If the sand is deep, two or more screws are sufficient.

DRIVE PIPE

Nominal Inside Diameter Inches	Thickness Inch	Nominal Weight per Foot Pounds	Number of Threads per Inch	Outside Diameter of Couplings Inches
3	0.217	7.54	8	$4\frac{1}{8}$
4	0.237	10.66	8	$5\frac{1}{4}$
6	0.280	18.76	8	$7\frac{1}{2}$
8	0.322	28.18	8	$9\frac{19}{32}$
8	0.363	32.00	8	$9\frac{19}{32}$
10	0.366	40.06	8	$11\frac{31}{32}$
12	0.375	49.00	8	$13\frac{31}{32}$
14	0.375	58.00	8	$16\frac{7}{16}$

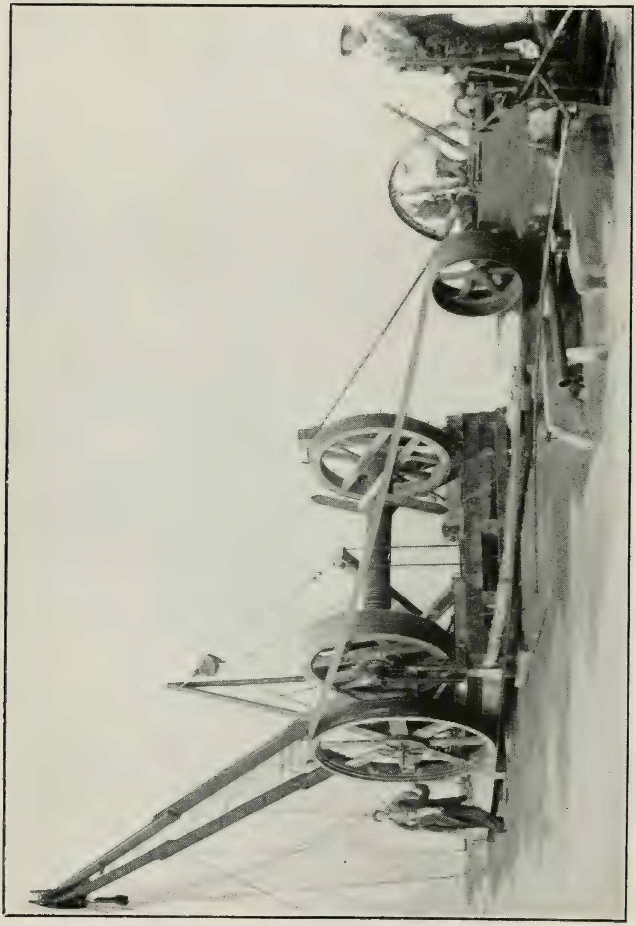


Fig. 21—PORTABLE DRILLING RIG SHOWING METHOD OF RAISING THE MAST

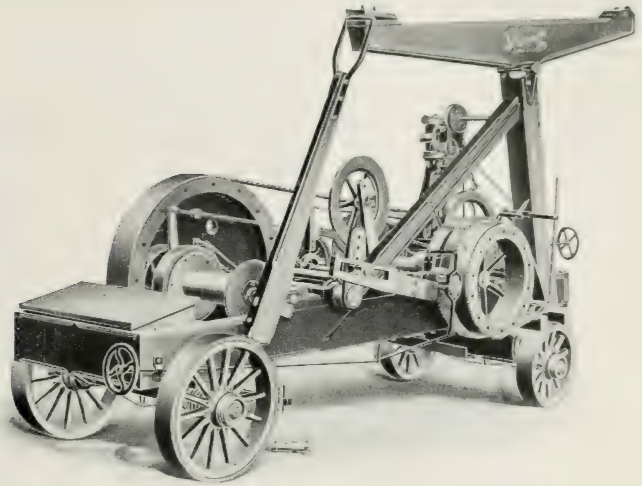


Fig. 22—PORTABLE DRILLING MACHINE

Wood Conductor Pipe—This style of pipe is often used in place of iron drive pipe where the rock is not very far below the surface of the ground. It is cheaper than the regular drive pipe and serves its purpose fully as well in keeping the mud or clay from caving into the hole while drilling.

Fig. 23—WOOD CONDUCTOR
Used in Lieu of Drive Pipe. Octagon, in Lengths of 16 Feet.

SIZES OF CASING

Nominal Inside Diameter Inches	Outside Diameter Inches	Nominal Weight per Foot Pounds	Number of Threads per Inch	Outside Diameter of Couplings Inches
2	2¼	2.16	14	2.687
2¼	2½	2.75	14	2.875
2½	2¾	3.04	14	3.187
2¾	3	3.33	14	3.500
3	3¼	3.96	14	3.781
3¼	3½	4.28	14	4.000
3½	3¾	4.60	14	4.250
3¾	4	5.47	14	4.625
4	4¼	5.85	14	4.687
4¼	4½	6.00	14	4.937
4¼	4½	9.00	14	4.937
4½	4¾	6.55	14	5.218
4½	4¾	9.00	14	5.218
4¾	5	7.58	14	5.562
5	5¼	8.00	14	5.781
5	5¼	10.00	14	5.781
5	5¼	13.00	11½	5.781
5	5¼	17.00	11½	5.781
5 3/16	5½	8.40	14	6.062
5 3/16	5½	13.00	11½	6.062
5⅝	6	10.16	14	6.062
5⅝	6	12.00	11½	6.625
5⅝	6	14.00	11½	6.625
5⅝	6	17.00	11½	6.625
6¼	6⅝	11.50	14	7.125
6¼	6⅝	13.00	11½	7.125
6¼	6⅝	17.00	11½	7.125
6⅝	7	12.45	14	7.687
6⅝	7	17.00	10	7.687
7¼	7⅝	13.50	14	8.220
7⅝	8	15.00	11½	8.625
7⅝	8	20.00	11½	8.625
8¼	8⅝	16.00	11½	9.312
8¼	8⅝	20.00	11½	9.312
8¼	8⅝	24.00	8	9.312
8⅝	9	17.50	11½	9.750
9⅝	10	21.00	11½	10.812
10⅝	11	23.00	11½	......
11⅝	12	25.15	11½	......
12½	13	35.75	11½	......
13½	14	42.02	11½	......
14½	15	47.66	11½	......
15½	16	51.47	11½	......

WEIGHT OF WATER IN PIPE OF DIFFERENT DIAMETERS IN LENGTHS OF ONE FOOT

62.425 POUNDS PER CUBIC FOOT

The following table will be found useful in computing the weight of water in a string of pipe or casing in a well.

Diameter Inches	Water Pounds	Diameter Inches	Water Pounds	Diameter Inches	Water Pounds
1	.3405	5	8.5119	10½	37.537
1⅛	.4309	5¼	9.3844	11	41.198
1¼	.5320	5½	10.299	11½	45.028
1⅜	.6437	5¾	11.257	12	49.028
1½	.7661	6	12.257	12½	53.199
1⅝	.8997	6¼	13.300	13	57.540
1¾	1.0427	6½	14.385	13½	62.052
1⅞	1.1970	6¾	15.513	14	66.733
2	1.3619	7	16.683	15	76.607
2⅛	1.5375	7¼	17.896	16	87.162
2¼	1.7237	7½	19.152	17	98.397
2½	2.1280	7¾	20.450	18	110.31
2¾	2.5748	8	21.990	19	122.91
3	3.0643	8¼	23.174	20	136.10
3¼	3.5963	8½	24.599	21	150.15
3½	4.1708	8¾	26.068	22	164.79
3¾	4.7879	9	27.579	23	180.11
4	5.4476	9¼	29.132	24	196.11
4¼	6.1498	9½	30.728	25	212.80
4½	6.8946	9¾	32.366	26	230.16
4¾	7.6820	10	34.048	27	248.21
				28	266.93

Water Pressure—The pressure of still water in pounds per square inch against the sides of any pipe or vessel of any shape is due alone to the head or height of the surface of the water above the point pressed upon, and is equal to 0.434 pounds per square inch for every foot of head, the fluid pressure being equal in all directions. For example: the pressure in pounds per square inch at the bottom of well tubing 1,000 feet deep and filled with water would be $0.434 \times 1{,}000 = 434$ pounds pressure.

Fig. 24—THE BURNING WELL AT MOORINGSPORT, LA., *1912.*
Showing crater formed by gas "blowing out" around casing
Width of the crater was about 500 feet

DEMONSTRATION OF MUD LADEN FLUID METHOD AS EMPLOYED TO CONSERVE THE NATURAL GAS RESOURCES IN DRILLING FOR OIL

Extract from Technical Paper No. 68, Bureau of Mines. 1914 demonstration made in the Cushing (Okla.) field.

Such enormous waste of an important natural resource indicates that the methods that were employed were faulty and that better methods, which shall at once be successful and practical, should be devised. For this purpose the Bureau of Mines proposed to investigate the possibilities of adapting the use of clay and water, which was devised for use with rotary rigs, and developed in Louisiana, Texas and California, to the dry-hole method of drilling practiced in Oklahoma. To accomplish this it was necessary to obtain the co-operation of well operators that a practical test and demonstration of the method might be made.

DEMONSTRATIONS OF THE MUD-LADEN FLUID METHOD

Demonstration at the Greis Well—The first well for demonstration was offered by Mr. Henry N. Greis, of Tulsa, Okla. This well was in the S. ½ SE. ¼ sec. 8, Tp. 17 N., R. 7 E. It had been drilled to a depth of about 1,700 feet on April 11, 1913, when gas from the Jones sand was encountered unexpectedly. The gas was ignited from a forge on the derrick floor, and the fire destroyed the rig.

After the rig was rebuilt, drilling was continued until May 2, when it was stopped in black shale at a depth of 2,140 feet. The hole was then filled with mud-laden water, and was allowed to stand full of this fluid until May 5, when drilling was resumed. The Jones gas, which had been escaping from the well, was successfully excluded from the bore hole by the fluid mud and gave no further trouble.

The hole was found to be bridged at a depth of about 1,700 feet, where drilling had ceased because of the fire, the strata there having slacked from contact with clear water during the time required to rebuild the rig. In drilling out this bridge considerable difficulty was encountered from caving, but the drilling tools were on the bottom of the hole by May 7. The hole continued to cave at about 1,700 feet, and it was decided to insert $6\frac{5}{8}$-inch casing. A special casing shoe 6 feet 4 inches long was made, and the casing was placed on May 9. Drilling was resumed May 10. The casing was lowered as the hole was drilled, and on May 11 it was securely seated at a depth of 2,147 feet, directly on top of the Wheeler sand.

On May 12 the hole was drilled 10 feet below the casing into the Wheeler sand. Bailing showed considerable gas, but the well was quiet and no gas escaped. The bailer and tools brought out thick mud and drilling became slower. May 14 a small quantity of sandstone was thrown into the well by the drilling contractor and drilled up, the tools going to the bottom of the hole and the bailer following to within 1 foot of the bottom, where it stuck. The sand line was parted in an effort to pull the bailer loose.

Fig. 25

GAS WELL NEAR CORPUS CHRISTI (1914) BEFORE THE GAS "BLEW OUT" AROUND THE CASING

On May 15 the bailer was grabbed by a "latch jack," but the latch was jarred through the bail. On May 16 a bell socket was used, which brought up pieces of the bailer. At no time was any difficulty experienced in getting a hold. On May 19 the bell socket stripped off the mandrel and work stopped for a new fishing tool. The bell socket was recovered May 20 by means of a tubing spear. On May 21 drilling was resumed in an attempt to drill out the remainder of the bailer, about one-half having been removed by the bell socket. On May 22 the sand pump that had been used for removing the pieces of the bailer as they were drilled up became fast in the hole and could not be loosened. The fluid was bailed out of the hole, and by means of a latch jack a hold obtained on the sand pump, which was easily removed on May 26.

Fig. 26—A BLOWOUT IN GOOSE CREEK FIELD (TEX.)

The gas pressure cleansed the well of mud and the tools were started in to drill up the bailer in the dry hole. Large pieces of steel were blown from the well by the gas, the flow of which increased gradually as the hole was deepened, until the tools would no longer drop with force enough to make hole. On May 28 the well was shut down and the flow of gas measured. The flow was more than 22,-000,000 cubic feet a day.

On May 31 the well was filled with mud-laden fluid. A gate valve was placed on top of the

$6\frac{5}{8}$-inch casing and connected by means of a swage nipple to a double joint of 10-inch casing provided with a top gate valve. The casing was anchored to "dead men" buried below the derrick floor and was securely braced in the derrick to avoid danger of its swinging so as to loosen the joints at the top of the well.

In filling the well with fluid the lower gate valve was closed, the upper one opened, and the chamber between the valves was filled with the fluid; the upper valve was then closed and the lower valve opened. The pressure in the filling chamber being equalized, the mud-laden fluid, owing to its weight, fell to the bottom of the well, being replaced in the filling chamber by an equal volume of gas. By again closing the bottom valve and opening the top valve, the gas displaced by the fluid was released and the chamber was ready for a new charge. This operation was repeated until the column of fluid in the well was so high that its hydrostatic pressure exceeded the rock pressure of the gas. The rest of the well was then filled by pumping the fluid directly in.

Drilling was resumed June 2 and a quantity of steel was removed from the well, some pieces exceeding 1 pound in weight. The tools dropped freely and broke up chunks of steel that were not broken by the tools when working in the dry hole with gas escaping.

On June 6 the drilling contractor again threw a small quantity of soft sandstone into the well and the bailer stuck on the first run after the stone had been put in. All efforts to pull the bailer out by the sand line failed and the sand line broke. The fluid was bailed out of the hole and the bailer recovered on June 8 by means of a latch jack. When the bailer was loosened it was thrown to the top of the derrick by the gas that was liberated by the removal of the fluid. The well was then filled again with the fluid and drilling continued until June 12, when the derrick was rigged

for casing. All 10-inch and 12½-inch casing were pulled on June 13, the surface casing and the 8-inch and the 6⅝-inch casing being left in.

On June 14, 2,177 feet of $5\frac{3}{16}$-inch casing with a lead shoe on the bottom was seated in the well and the mud-laden fluid bailed out. The lead shoe and casing proved tight against the pressure of the column of fluid on the outside, which stood to the top of the 6⅝-inch casing.

Drilling was resumed and 22 feet of hole was made in advance of the casing. This hole struck a second gas sand, and the well was shut in and again filled with the fluid on June 17. The $5\frac{3}{16}$-inch casing was withdrawn on June 18. The hole was then reamed from 2,177 to 2,198 feet and the $5\frac{3}{16}$-inch casing was reset June 20 with a $5\frac{3}{16}$-inch by 6⅝ inch conical sleeve packer, carrying 26 inches of rubber on the bottom. The fluid was bailed out and the casing found to be tight, the well was quiet, and no gas was escaping.

Drilling was resumed June 21. Oil was encountered the next day, and on June 23 was spraying into a tank with a fine showing for a large production. During the first 24 hours after the oil started to flow into the tank the gaged flow was 60 barrels, and on June 25 drilling was discontinued.

Results Obtained by the Test—This demonstration of the well-drilling method proposed by the Bureau of Mines proved the following points:

1. The escape of gas from a well during drilling can be controlled, and formations can be sealed so as to prevent the further escape and waste of gas.

2. The sealed formations may be reopened at any time by removing the fluid from the well, the pressure of the gas cleansing out the mud so that the yield will not be affected.

3. By sealing off gas with mud-laden fluid it is possible to drill entirely through a gas-bearing sand without wasting gas.

4. A record of the gas bearing formations can be obtained with an accuracy that is impossible with the "dry-hole" method of drilling, for the reason that on drilling a hole "dry" the gas blows all the finer drill cuttings from the well and only occasionally are fragments found that are large enough to show the character of the formation penetrated.

The following record indicates the character of the formations penetrated during the demonstration, the terms "sand" and "lime" are those recorded by the driller, the samples not having been examined by a geologist:

RECORD OF WELL FROM TOP OF WHEELER SAND TO OIL SAND

Depth	Material		Estimated volume per day of gas flow
	Thickness	Kind	
Feet	*Feet*		*Cubic Feet*
2,140 to 2,147	7	Black shale	
2,147 to 2,173	26	Blue-gray lime (gas)	22,000,000
2,173 to 2,179	6	Gray sand	
2,179 to 2,181	2	Brown Sand	
2,181 to 2,186	5	Blue shale	
2,186 to 2,191	5	Black shale	
2,191 to 2,199	8	Gray lime (gas)	5,000,000
2,199 to 2,213	14	Gray sand (gas)	300,000
2,213 to 2,225	12	Gray sand (oil)	

The time spent in the different operations at this well was as follows:

May 2, 1913, started demonstration.
June 25, 1913, completed demonstration, with well producing oil.

	Days
Drilling, 8 days with double tours, 11 days with single tours	19
Fishing and shutdowns	17
Drilling on lost bailer and removing bits of steel	8
Casing	5
Rigging up and filling well with mud-laden fluid	5
Total elapsed time	54

Core Drill—It is very unusual to find the Core Drill outfit at work in any gas field. While this system of drilling is commonly used for drilling wells for elevator plungers and for geological tests, it is seldom used in drilling for gas.

It is a rotary system for use in Paleozoic formations, differing greatly, however, from the rotary employed in the Louisiana and Texas fields, where the formation is Cretaceous. The actual cutting is done by a tube or casting, with about a one-half inch surface or face, revolving on top of what is called "steel shot." The "steel shot" simply consists of small pieces of chilled steel, rather rough in shape, and averaging about the size of B. B. shot. Above the bit, or cutter, is the reducing plug, connecting same with a calix. The calix is connected with the tubing, which is two- or three-inch and runs to above the derrick floor through rotary driving apparatus. A stream of water is pumped into the tubing, carrying with it the chilled shot as required and depositing the shot under the bit or cutter. This method cuts a core which is taken out in pieces varying from a few inches to fourteen feet in length. The great advantage of this system is that it shows the geological formation from the surface to the bottom of the well. After the water passes in and around the bit or cutter, it flows upward, carrying with it the silt or drilling which is deposited in the top of the calix. The tendency of the bit drill is to drill a perfectly smooth hole, thereby enabling the packer to set without chance of leaking.

Breaking off the core is done with the aid of the circular bit, which is slightly tapered towards the top, and by placing gravel in the stream of water, which is pumped into the tubing. When the driller has cut sufficient core to pull out, instead of placing the shot in the stream of water pumped into the tubing, gravel is used. The gravel is deposited around the inside of the tapered drill. This gravel becomes wedged between the core and the bit and during the process

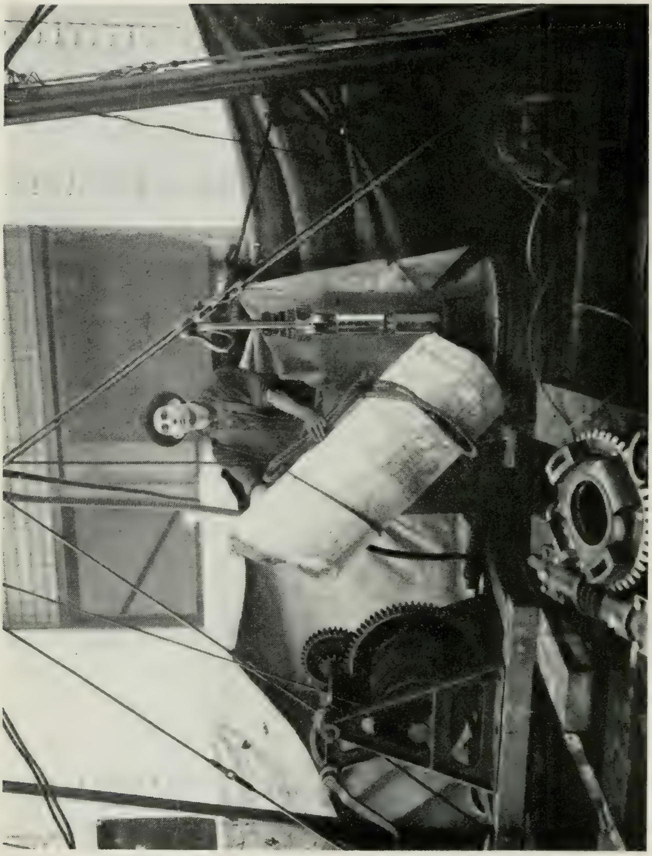


Fig. 27—CORE DRILL AT WORK

Taking out a 22-inch core from a 24-inch hole for an Elevator Plunger, at Birmingham, Ala.

of revolving, practically twists the core off at the bottom, after which, the tubing and the bit are pulled out, the calix is emptied of its drillings and the core taken out of the bit. The sides of this core are practically smooth; in fact they remind one of a marble column. This method is spoken of as the "core drilling system without the use of diamonds."

The derrick used is of special make, being 125 feet high and of bolted tubing.

The well is started, before striking the rock, by placing a shoe and drive head, and revolving the same as a regular drill, using the water system until solid rock is reached.

It has been possible to drill a little over 100 feet in one tower while drilling in comparatively soft rock.

While this method seems rather expensive to a practical gas man, it is of great advantage to be able to see the rock formation at different depths and to know exactly where each portion of the core came from. In drilling for gas by the common standard method, one is merely able to examine the drillings and can only guess within four or five feet of the exact depth from which they came.

With this method the driller looks to his cable for measurement. With 1000 or 1500 feet of cable in the hole, the stretch will amount to considerable. A steel measuring line can be used showing the depth or location of the sand more accurately. Of course in shooting the well, pieces of rock of sufficient size to enable one to make a very careful examination may be blown out. But this does not determine the exact depth from which they came.

Drilling Gas Wells in Lake Erie—During the past few years a profitable gas field has been located along the north shore of Lake Erie in the vicinity of Selkirk, Dunneville and Port Maitland, Ontario The first wells were drilled but a short distance from shore, where the depth was not over one or two feet and the operations could be carried on at any

time of the year. Gradually the locations were made further from the water's edge, until finally one well was drilled by the North Shore Gas Company through the ice one-half mile from shore. These wells have proved to be of medium size, with a rock pressure ranging about two hundred pounds to the square inch. The gas comes from the Medina gas sand at a depth of about nine hundred feet, and is of excellent quality. No tubing is used, but the wells are cased off with $5\frac{5}{8}$-inch casing to nearly the full depth, or just above the gas sand.

Fig. 28—GAS WELL IN LAKE ERIE
Located about one-half mile from shore in twelve feet of water. Concrete pier is hardly visible above water level. Note lead line from well just level with water.

At the top of the casing is placed a $5\frac{5}{8}$-inch to 2-inch reducing cap through which is hung a $\frac{3}{4}$-inch water siphon reaching to the bottom of the hole. The siphon takes care of any water that might come in the hole below the casing. The wells are "blown off" regularly, same as with those located on land, the employee being obliged to use a boat in summer, while in winter he travels over the ice to the different wells. Concrete piers are built around the wells to protect them from the ice in the spring and the waves during severe storms.

Leases on lake land are obtained from the Government, to which a royalty is paid of one-half cent per thousand cubic feet of gas taken from the wells. The land is divided into

blocks from two to three hundred feet square and all wells drilled must be located in the lake beyond the low water mark.

The well lead lines run onto the land where a drip takes care of the moisture in the gas. Here it is metered through large capacity meters and sold to pipe line companies.

In January of 1912 the Lake Shore Gas Co. of Selkirk, Ont., made a location about one-half mile from shore, upon the ice where it was thought the water was not more than three or four feet deep. Through miscalculation the depth proved to be twelve feet. As the winter proved to be a very cold one the drilling was carried on successfully, and was completed just before the spring thaw.

Fig. 29—GAS WELL IN LAKE ERIE
Located near shore where the water is but two or or three feet deep. Note the concrete pier with sloping side toward direction of prevailing waves.

All timbers for the rig were moved to the location the same as on land. A standard rig was used with coal for fuel under the boiler. Only necessary tools were drawn to location. The boiler was set with blocks under the stack end and the fire box end was set on a twenty-foot joint of eight-inch casing. The rig was guyed with wires to stakes driven through the ice. The depth of the water was not determined till spudding was started.

The heat of the boiler soon melted the ice under the fire box but not under the stack end. The ashes dropped through

Fig. 30—PUTTING OUT A BURNING WELL IN THE CANEY FIFLD BY USE OF A HOOD AND LEAD LINE TO CARRY GAS TO ONE SIDE FROM WELL

the hole in the ice into the lake. The joint of eight-inch casing proved to be an absolute necessity in preventing the boiler dropping into the water. The derrick timbers were not imbedded in the ice but placed on top and proved to be sufficiently rigid in drilling.

The drilling progressed rapidly in calm weather. During severe storms operations were stopped because of the liability of freezing pipes and danger of the derrick being blown over. These shut-downs were necessary to allow the water around the boiler fire-box to freeze, as with continued fire under the boiler the ice kept melting further away until both the boiler and joint of casing threatened to drop into the lake.

The well was completed late in February and the boiler and derrick were moved off the ice under severe conditions, as the spring thaw had set in. Several times the teams hauling the material broke through the ice, but with all the hardships experienced none of the outfit was lost.

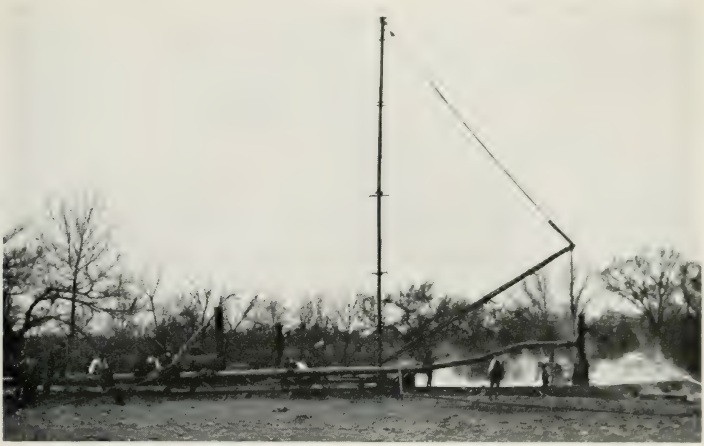


Fig. 31—SAME WELL AS FIG. 30. VIEW SHOWING MAST ERECTED ON CAR AND RUN ON TRACK UP TO A POINT WHERE HOOD COULD BE LOWERED OVER BURNING WELL

This particular well was drilled to a depth of 920 feet and showed a flow of 500,000 cubic feet per day.

As soon as drilling was finished and before the derrick was removed from the location, the construction of the concrete pier was started. This required the building of cribbing around the well to keep out the water while the cement was setting. The pier is built with a sloping side facing the direction of the prevailing waves.

A two-inch lead line was laid on top of the ice from well to land and dropped through the ice to the bottom of the lake.

Well Record—A complete and accurate record or log of the well while drilling should be kept by either the contractor or the field man. All formations and known sands should be shown with their proper names. The depth of finding oil, gas, or water, and a statement of the thickness of the sands, with an opinion of the quality of the sand, should be included in the report.

Shooting—Shooting consists of exploding a charge of nitroglycerin in the well on a level with the gas vein, the object being to fracture the gas-bearing rock to allow a freer movement of the gas from the gas sand to the well proper.

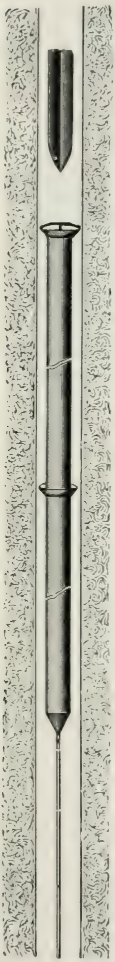


Fig. 32

During the process of drilling, accurate measurements should be taken with a steel measuring line, showing the depth of the sand, the thickness of same, and the amount of pocket below the sand. If the sand is hard and the well is under 1,000,000 cu. ft. capacity per day, eighty quarts of nitroglycerin is the proper shot, and for soft sand with the same size flow, forty quarts. In wells of larger flow than 1,000,000 cu. ft. per day, it is not advisable to shoot on account of the danger in lowering the shell into the well. The shot should be placed on top of the proper amount of tin tubing anchorage, the length of the latter being determined by the log of the well previously taken. The main body of the shot should rest opposite the sand where there is no water vein directly underneath the sand, one shell should be placed below the bottom of the sand to enlarge the pocket for the accumulations of cave-ins, sand etc.

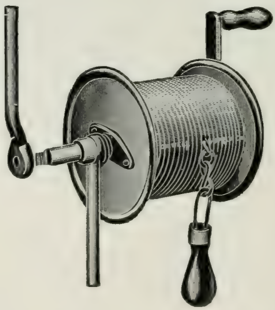


Fig. 33—STEEL LINE FOR MEASURING DEPTH OF WELL

Note brake lever hanging from shaft, also weight which keeps line taut while in use and assists in finding bottom.

In shooting a gas well, the operator should be well versed as to the character of the sand, as some gas wells are liable to be ruined by shooting.

Nitroglycerin — Nitroglycerin is a heavy, oily, explosive liquid $C_3 H_5 (No_3)_3$. The color varies from water white to amber, obtained by treating glycerine with a mixture of nitric and sulphuric acids. It produces by detonation

Fig. 34—A NITROGLYCERIN MOTOR TRUCK

about fourteen thousand times its own volume of gas. Compared with gunpowder it is eight times as powerful weight for weight, or thirteen times as powerful, volume for volume. It is shipped in ten quart cans and transported from factory to field by wagon or automobile.

Nitroglycerin freezes at about 55 degrees fahr. and must be thawed before lowering into the well for shooting.

It is a very dangerous explosive to handle as it requires due care and skill to prevent a premature explosion.

After shooting, the empty cans should be exploded at a safe distance either by use of a fuse and a percussion cap or by shooting at them with a rifle.

Solidified Nitroglycerin—This explosive is made by putting nitroglycerin through a process whereby its nature is changed from liquid to a gelatinous substance about the consistency of soft putty, but more rubber like. It is four per cent more powerful than liquid nitroglycerin, weight for weight It is somewhat insensitive as compared to the liquid, —this being necessary to have it comply with the Interstate Commerce Commission regulations. The color varies with the color of the nitroglycerin used in its manufacture.

Fig. 35

Solidified nitroglycerin is put up in round sticks, wrapped with paper similar to dynamite, and is packed in small boxes. It can be shipped by freight to point of destination. This is a great advantage over the liquid nitroglycerin as it eliminates the necessity of hauling it by team across country, which is a hazardous operation especially in season when the roads are rough.

When loading, the sticks of solidified nitroglycerin are broken by hand and packed into the shell by the aid of a wooden stick. See figures number 36 and 37.

In shooting, the shells must be placed in the hole one above the other, that is, with no anchorage in between, otherwise the entire shot might not explode.

After the loaded shells are placed in the hole, the firing is done by dropping a "jack squib" with a lighted fuse attached to the percussion cap in the interior of the squib. The "jack squib" is filled with solidified nitroglycerin.

Torpedo — This consists of a tin shell or tube a few inches in diameter according to the size of the well to be shot and in lengths of from two to ten feet. The end of the shell carries a small tin tube soldered on to the point to fit over the top of the anchorage or shell below. The top shell carries a firing head under which is placed a percussion cap. The flat round plate on top of the firing head prevents the go-devil from passing by without firing the percussion cap. This flat plate is quite necessary where there is plenty of water in the hole which would greatly decrease the speed and force of the go-devil in its downward course.

Fig. 37 — LOADING A SHELL WITH SOLIDIFIED NITROGLYCERIN

Fig. 36 — PREPARING SOLIDIFIED NITROGLYCERIN TO LOAD INTO SHELL FOR SHOOTING GAS WELL

Shot Anchor—Figure 39 shows the anchorage used below the filled shells of nitroglycerin or solidified nitroglycerin. It consists of a tin tube of about two inches in diameter with a pointed end at the bottom and the top end made to fit over a tube of like diameter at the bottom, of the bottom shell.

Fig. 38

Fig. 39

Go-Devil—This consists of a three edged elongated piece of cast iron, pointed at one end. It weighs about twenty pounds and is made of cast iron so that it will be entirely broken up at the instant of exploding the shot and not come out of the hole in large pieces or clog in the hole.

After placing the loaded shells in the hole at the proper place the go-devil is dropped and explodes the shot.

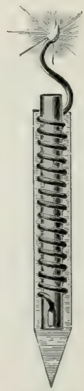


Fig. 40

Jack Squib—This is used to explode the shot in the hole. It consists of a small tin tube pointed at one end and filled with solidified nitroglycerin or dynamite with a fuse and percussion cap within the interior. Before dropping in the hole the end of the fuse is lighted. The fuse is long enough so that the squib will not explode before reaching the position of the loaded shells in the hole. It is used in firing solidified nitroglycerin shots.

Cleaning Out—After shooting and before cleaning out, the well should be allowed to stand over night to allow for the caving in of the sand loosened by the shot. The well should be thoroughly cleaned out until the steel measuring line can be run to the full depth of the well prior to the shot.

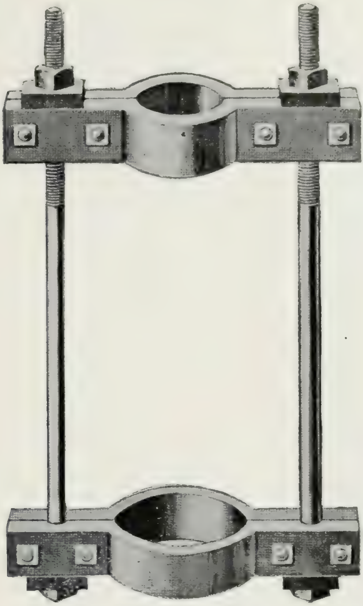


Fig. 41—ANCHOR RODS OR CLAMP

Used in anchoring the tubing to the casing or drive pipe. This, with the assistance of the weight of the tubing in the well, keeps the gas under control, and in addition, expands the rubber packer, thereby preventing the leakage of gas around it from the portion of the well below the packer.

Fig. 42—PERFORATED PIPE OR TUBING

Placed in the string of tubing opposite the gas sand. The holes are ¼-inch and drilled on four sides of the pipe about one foot apart for the full joint length.

Tubing and Packer—The gas conductor or tubing of a gas well is made of extra heavy pipe of from two to four inches in diameter, the size being selected according to the flow of the well. Some gas men believe that it is policy to use as small a tubing down to 2-inch, as is possible, even though it be necessary to "pull in" the first few joints when starting to tube the well. The idea of this is that it is easier to get water out of the well and, not being able to drain the well as quickly of the gas, the life of the well would be longer.

Fig. 43—DISC WALL PACKER

A packer consists of a steel plunger with a rubber ring fitting close to the walls of the well, the rubber being ten to twenty inches in length. An anchor packer has the tubing connection or thread on the top and bottom, while the disc wall packer has tubing connection on top only, the rubber being supplemented with a set of jaws working over a cone and held in place by a spring and a cast iron disc. If the packer is an anchor packer, it is placed a few joints off the bottom of the tubing and is anchored in place, after the tubing rests on the bottom of the well, by the weight of the tubing on top of the packer with the assistance of anchor irons and rods pulling the tubing downward on the surface. The amount of tubing underneath the packer is dependent upon the height of the sand above the bottom of

Fig. 44—Sectional View of Gas Well with 3-in. Tubing and ¾-in. Water Siphon.

the well and the location of the hard strata in which it is desired to set the packer above the gas sand. The joint of tubing which would come opposite the gas sand is perforated with ¼-inch holes drilled through the pipe the full length of the joint, with about a foot space between perforations

The disc wall packer is set on the bottom of the first joint of tubing that is let into the well. When the packer reaches the proper distance or opposite the location desired to set the packer, a short piece of pipe—¾-inch pipe preferred— is dropped through the tubing. This breaks the disc in the packer, thereby releasing the spring and jaws, after which the packer will support the tubing without use of elevators and the tubing can be anchored down on the surface without liability of packer dropping. The disc wall packer can be pulled out of the well and a new disc inserted in the packer if it is desired to lower the packer below its first location or to use the packer again in another well.

It is a good idea to use a 3-foot nipple and collar just above the packer in the string of tubing with a right and left hand thread, so if at any time in the future it is desired to pull the tubing and the packer has become stuck, the whole string of tubing can be turned at the left hand thread and pulled.

In event of the packer leaking after being anchored and the well is shut in, blow off well and put in one-half bushel of wheat and four or five pounds of shot on top of the wheat. The shot will weigh down the wheat and assist in making the

packer tight. If there is no water on top of the packer, put in two or three barrels of water. After being allowed to stand two or three hours, the well can be shut in to determine the effectiveness of the operation.

All tubing should be painted before placing in the well, not forgetting tong marks after it is set up.

In wells of 10,000,000 cubic feet daily capacity and larger, where a long string of casing has been used and the pressure does not exceed 300 pounds to the square inch, the casing itself may be used as tubing.

Fig. 45—CAPPING A LARGE GAS WELL IN THE CANEY FIELD (1907)

Open Flow Capacity of Well, 80,000,000

When a gas well is overhauled (i. e., the casing, tubing, and water pipe are pulled and renewed), it is good policy to test the well before and after the work.

Often an old gas well, whose flow and rock pressure have dropped, can be shot to advantage. This requires the pulling of the tubing and water pipe prior to shooting.

It is advisable to shoot the well with at least 100 feet of water on top of the shot. Dry shooting is less effective on the sand though more spectacular.

TUBING

Nominal Inside Diameter Inches	Thickness Inch	Nominal Weight per Foot Pounds	Number of Threads per Inch	Outside Diameter of Couplings Inches
1	.134	1.67	11½	1.687
1¼	.140	2.24	11½	2.062
1½	.145	2.68	11½	2.375
2	.154	4.00	11½	2.937
2 patent	.174	4.50	11½	2.937
2½	.204	5.74	11½	3.5
3	.217	7.54	11½	4.062
3½	.226	9.90	11½ and 8	4.687
4	.237	10.66	10 and 8	5.187
6	.280	18.76	8	7.343

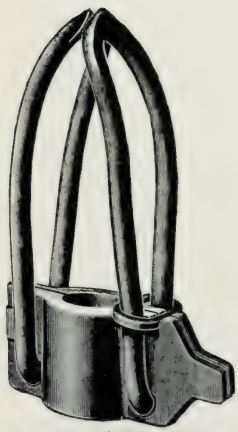


Fig. 46—ELEVATORS

Elevators—These are used for letting in and pulling out, drive pipe, casing, tubing, and water pipe. The size shown in Fig. 46 is for 2-inch tubing. In using elevators always see that both elevator links are caught in the tackle block hook.

Dry Holes—In the event of drilling a dry hole and striking the gas or oil sand, it is very essential to plug the hole just above the sand with either a rubber or wooden plug. If wood is used, dry pine is the best, as it will swell soon after being immersed in the water in the bottom of the hole and make a perfectly tight fit.

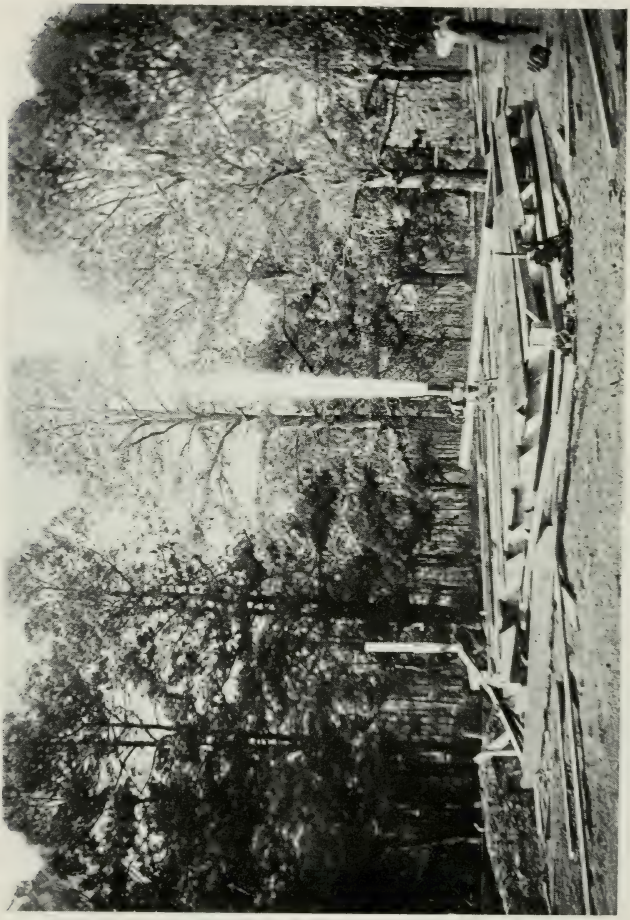


Fig. 47—A COMPLETED GAS WELL READY FOR CONNECTION WITH MAIN LINE

Fig. 48—WOOD DRY HOLE PLUGS

Well Connections—After a new gas well has been shut in and anchored it should be blown off a day or two later and the anchor rods re-tightened. In connecting up a "tubing blow-off" on a gas well, the blow-off should point at right angles from the tubing with no angles between the blow-off opening and the tubing. Otherwise the reaction of the gas issuing from the blow-off will tend to force the blow-off connection around and may result in a serious accident.

Water Propositions—With gas wells of medium size making water, use a ¾-inch "siphon" or water line hanging from the top inside of the tubing and with a "blow-off" on the top end. The bottom of the "siphon" should be plugged and hung one foot from the bottom of the well. Perforate the joint of pipe opposite the main gas sand with ¼-inch holes, drill through both sides of the pipe and space one foot apart. If blown often, this method keeps the water out of the well.

Where there is no "floating sand" in the well, the same method can be installed with 1-inch working barrel and anchorage on bottom of ¾-inch, using the ¾-inch as a sucker rod as well as a conductor for the water. The top of the ¾-inch should work through a

Fig. 49—Gas Well "shut in" ready to connect with main line

stuffing box on the top of the tubing with a small walking beam and gearing, using a horse for power, or a two to four h. p. gas engine.

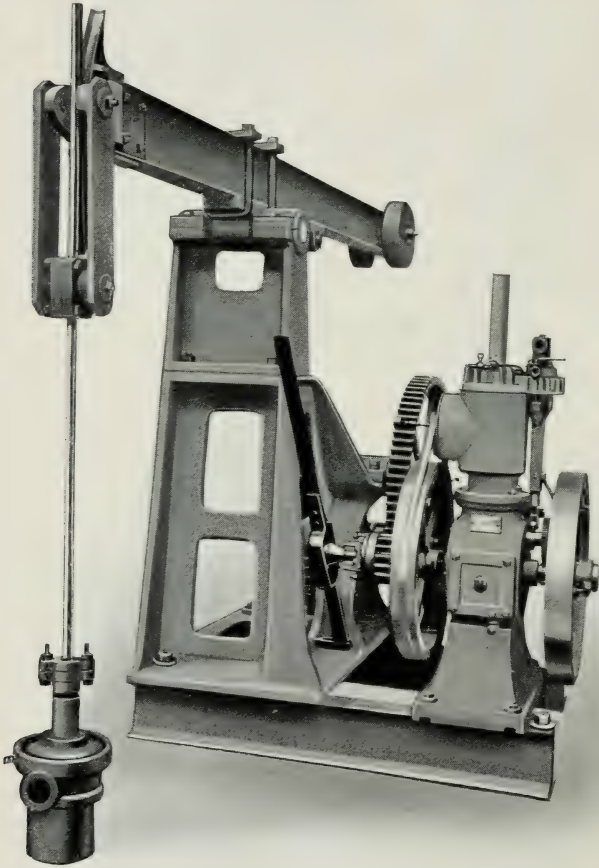


Fig. 50—PUMPING POWER FOR PUMPING OIL WELLS OR WATER FROM GAS WELLS

In equipping gas wells with ¾-inch water pumping outfits where the size of tubing is over 3-inch, a cast iron

spider can be used on every second or third joint. The spider fits loosely in the tubing and is made to slip over the ¾-inch, but not large enough to slip by a ¾-inch collar. This method prevents the ¾-inch from weaving while pumping.

There are special made gas pumps which can be used in connection with this ¾-inch without wasting any gas.

With the blowing out method, water can be raised through a ¾-inch "siphon" from a depth of 1200 feet with a 75-pound gas pressure, and from a depth of 1500 feet with 125-pound gas pressure.

Cement will not set in a heavy mineral water in a gas well. A small gas well cannot be properly "blown off" and cleaned of water where casing is used in place of tubing.

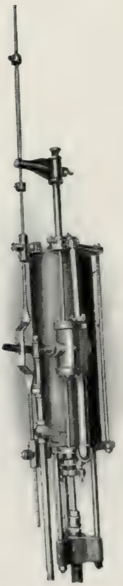


Fig. 51—PUMPING HEAD

Pumping Powers—The pumping power is adapted for pumping small oil wells in isolated localities. It is also used extensively for pumping water from gas wells down to a depth of 3,500 feet by using the ¾-inch water line for both tubing and sucker rods. With a friction drum attached to the power, it is possible to pull the tubing and sucker rods from wells 2,600 feet in depth. With a larger pulley on the engine shaft, which will increase the speed, the drum may also be used for bailing.

Pumping Heads—Pumping heads are clamped to the tubing and are used for pumping water from gas wells, using either gas, air or steam under pressure for power. The water

is pumped through a $\frac{3}{4}$-inch line same as with a pumping power. The heads for steam are 12 inches in diameter, 34 inches long, with a 30-inch stroke; for air and gas they are 12 inches in diameter, 36 inches long, with a 32-inch stroke.

Heads can be operated on pressures ranging from 40 lb. to 400 lb., and will pump wells any depth down to 2600 feet.

Capping—This operation merely consists of placing a gate on the tubing or casing and "shutting in" the well.

If, in drilling a gas well, a volume greater than 35,000,000 cubic feet daily capacity is anticipated, and the conditions of the well are favorable for casing to be used in place of tubing, screw a gate on the casing and reduce the size of the drill or bit just before drilling into the gas vein. If reducing the size of the bit is objectionable, use a swedge nipple and a gate one size larger than the casing.

Gas Well Drip—A gas well should not be connected without using a drip near the well, whether the gas be absolutely dry or not.

This drip should be placed from three to four joints of pipe distant from the well. The length of the lead and tail of the drip is dependent entirely upon the amount of water in the well. For a 2-inch or 3-inch lead line use 6-inch pipe in the drip. For a 4-inch lead line use 8-inch pipe in the drip, and for a 6-inch lead line use 10-inch pipe in the drip. A stop cock should never be used on the blow-off of the drip.

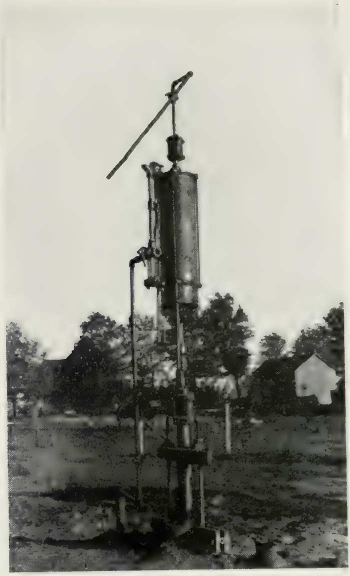


Fig. 52—Gas Pump for Pumping Water from Gas Well through ¾-inch Pipe, using the ¾-inch as a Sucker Rod and Tubing for Water Discharge Combined.

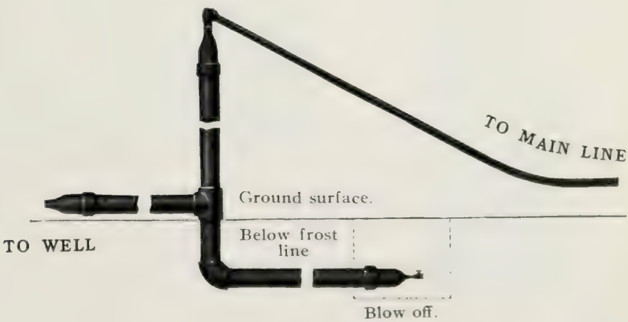


Fig. 53—GAS WELL DRIP

Gas Well Lead Lines—A gas well lead line is a pipe line connecting the well with the main line. Where there is liability of the pressure in the field line or main line exceeding the pressure on the gas well, a check valve should be placed on the lead line. Stopcocks should not be used on gas well lead lines.

Care of Gas Wells—After a gas well has been completed and it is desired to move the derrick, a "three-pole derrick" or "gin poles" can be erected, or a single mast or gin pole can be used in case of emergency, for pulling tubing or water pipe.

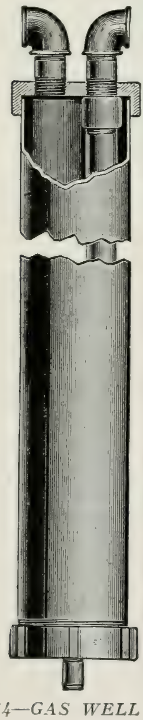


Fig. 54—GAS WELL DRIP

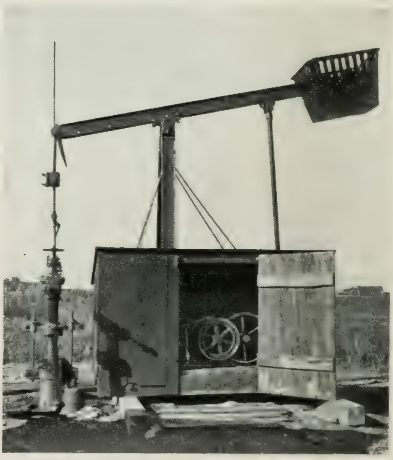


Fig. 55—Walking Beam Method of Pumping Water from a Gas Well. Power is furnished by 3 h. p. gas engine and the water is pumped through the ¾-inch siphon. The ¾-inch pipe is used as a sucker rod and tubing.

The common method of expelling water from the well by blowing the gas into the atmosphere is an extravagant waste of gas. Wherever it is possible, the $\frac{3}{4}$-inch siphon water line with pump attachment should be used.

A gas well cannot be blown off and cleared of water where casing is used in place of tubing.

In the event of a gas well constructed with a $\frac{3}{4}$-inch siphon becoming flooded, the siphon can be pulled a few joints and the well shut in; then, after an accumulation of pressure, an attempt can be made to raise the water. If the $\frac{3}{4}$-inch pipe, when opened, does not make a showing of water, it should be pulled one or two points more and the process repeated until the level of the water in the well is determined. After each attempt to raise the water, the well should be capped and allowed to stand long enough to permit the gas pressure to raise to at least 50 lb. After the well begins to throw water and the water level is lowered to the bottom of the $\frac{3}{4}$-inch pipe, the pipe should be lowered half a joint and the operation repeated until the full length of the $\frac{3}{4}$-inch pipe is back in the well. This method will often save the expense of erecting a derrick and bailing.

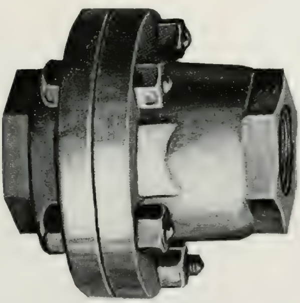


Fig. 56—EXTRA HEAVY SWING CHECK VALVE

When a gas sand becomes coated with paraffine or salt the only sure method of cleaning out the well is by the "steaming process." This merely consists of turning live steam at about 125 lb. pressure, into the $\frac{3}{4}$-inch siphon and up through the tubing into the atmosphere. The boiler should be placed on the windward side and about two hundred feet from the well.

It is policy to "blow off" gas wells of medium size, especially those making water, in summer as well as in winter, even though the well be closed in, except where pumping apparatus has been installed to free the well of water. It is not necessary to blow a well as often in summer when the well is shut in as it is in the winter or when feeding into the line.

In the event of a leak developing in the tubing of a gas well, the tubing should be pulled and tested under pressure on the ground.

Salt Water Propositions—Where gas wells are troubled with salt, which frequently clogs the tubing to such an extent that gas cannot pass through it, it becomes necessary to dissolve the salt, which is done by pouring water down the well. To admit fresh water, a "swaged water jug" which is made of a piece of 6⅝-inch casing about three feet long, swagged at both ends to two inches is used. This is screwed into the top of the tubing, and holds about four and one half gallons of water.

A bailing machine is then placed in position to agitate the fresh water in the tubing in order to dissolve the salt and bail it from the well.

It often happens that ten or fifteen joints of tubing, aggregating 200 to 300 feet, will fill up solid with salt.

When fresh water fails to dissolve the salt, it becomes necessary to pull the tubing and to "shoot" the well; that is the sand in the bottom of the hole. Usually from 20 to 60 quarts of nitro-glycerin are used, depending upon the thickness of the sand.

The well is then cleaned, re-tubed and treated with fresh water. From 30 to 100 gallons of fresh water is considered a "dose" and is allowed to remain from twenty to twenty-four hours on the salt before blowing out. This has

the effect of dissolving the salt and washing the gas sand. It requires extreme care in handling to prevent the well clogging and being ruined.

In certain localities where the gas is found in the Clinton sand it is found necessary to "water" a well twice weekly, and then it is only possible to keep them in commission about half the time, while others only require attention once or twice a month.

Fig. 57—WATERING A GAS WELL

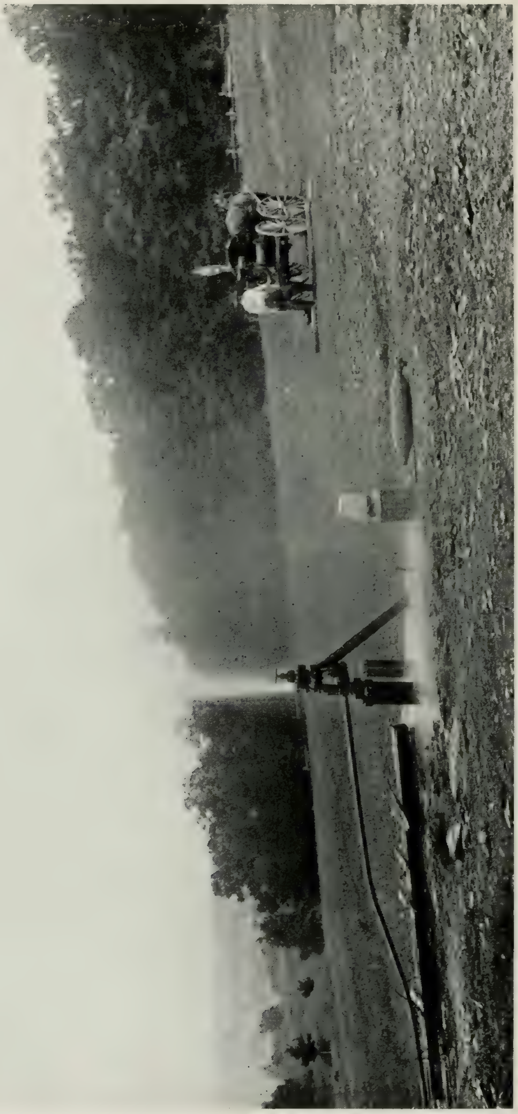


Fig. 58—SWABBING A GAS WELL

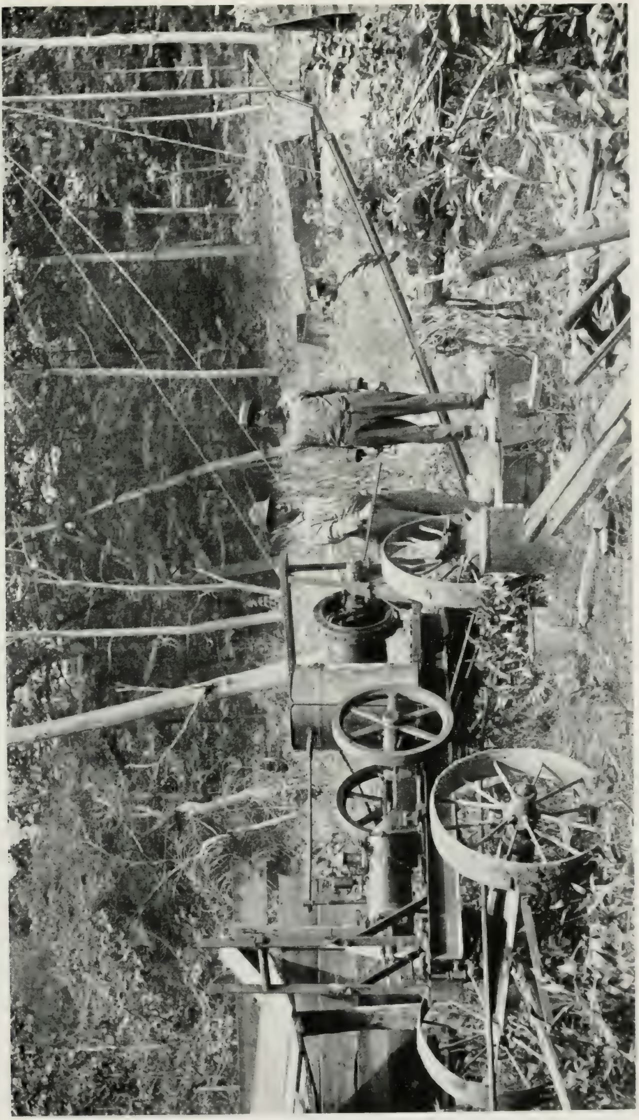


Fig. 59 Bailing Water from a Gas Well with an 8 H. P. Portable "Bailing Machine." Bailer is 16 ft long and is made of 1¼ in. Pipe

The Clinton Sand which extends from Hocking County on the south to Lake Erie on the north, is not only one of the most prolific gas sands ever developed, but probably contains more salt than any other field. This field is different from many others in that it contains but one paying gas formation.

Use of Abandoned Gas Wells—Many times gas wells are abandoned even though they can supply enough gas for a few consumers. It is often profitable for land owners, where gas wells are abandoned on their property, to purchase from the gas company abandoning the well, the drive pipe casing, and tubing, in order that it may be left in the well, thereby furnishing enough gas for one or more consumers.

Sometimes after wells are abandoned and become filled with water, gas continues to bubble through the water. To save this construct a large galvanized iron drum and place over the well. The drum should be set in a water filled pit surrounding the well with guide posts, the same as a gas holder to allow the drum or tank to raise with increasing volume of gas. Connection can be made with the top of the drum by a one-inch rubber hose to an iron pipe leading to the consumer's house. This method will always insure a low pressure, as too much pressure will cause the drum to raise until the gas breaks the water seal and escapes into the atmosphere. To increase the pressure, place a weight on top of the drum. It must be borne in mind that while the leaking gas from an abandoned well might not run a stove or furnish enough gas for one consumer continuously, the gas could be collected in the drum during the twenty-four hours in sufficient amount for occasional use.

PART FOUR

Measurement of Gas Wells

BASIS OF MEASUREMENT OF NATURAL GAS—PITOT TUBE FOR TESTING AND OPEN-FLOW TESTING OF GAS WELLS — MINUTE PRESSURE TESTING — ROCK PRESSURE — WORKING CAPACITY OF GAS WELLS.

Basis of Measurement of Natural Gas—The value of natural gas lies almost wholly in its ability to produce heat, and this is directly proportional to the weight. For example, two pounds of a given quantity of gas will produce just twice the heat that one pound will. It is not convenient, however, to deal with gas in units of weight, and hence it is the universal custom to speak of gas quantities as so many volume units, such as cubic feet or cubic meters.

Gas being an elastic fluid and having the property of entirely filling any vessel in which it may be contained, the actual weight of gas present in any given volume depends not only on the extent of that volume, but also upon the pressure and temperature of the gas. It is necessary, therefore, when speaking of any volume of gas, to have a definite understanding of the pressure and temperature under which the volume is measured.

It has long been the custom for natural gas men to consider 60 deg. fahr. as the standard temperature basis of measurement, and four ounces (=0.25 lb.) per square inch above an assumed mean atmospheric pressure of 14.4 pounds per square inch, as the standard pressure basis. These values are equivalent to 520 (=460 plus 60) fahrenheit degrees, and 14.65 (=14.40 plus 0.25) pounds per square inch above the absolute gross temperature and pressure, respectively.

Throughout all that follows in this book, unless otherwise specifically stated, it is to be understood that the above mentioned standards of measurement are to apply.

The specific gravity of gas as referred to air, and its flowing temperature, also enter into the computations in certain formulas and tables to follow, and these will always be considered equal to 0.60 specific gravity and 60 deg. fahr. (=520 degrees absolute) respectively, unless otherwise stated.

Pitot Tube for Testing the Open Flow of Gas Wells—The most accurate way of testing the flow of a gas well is by means of the pitot tube. This is an instrument for determining the velocity of flowing gas by means of its momentum. It usually consists of a small tube, one end bent at right angles, which is inserted in the flowing gas, just inside the pipe or tubing and between one-third and one-fourth of the pipe's diameter from the outer edge. The plane of the opening in the tube is held at right angles to the flowing gas. At a convenient distance, varying from one to two feet, an inverted siphon or U-shaped gauge is attached to the other end, which is usually half filled with mercury or water. If the flow is over five pounds to the square inch a pressure gauge is required.

In small sized wells of not over four million feet, a 12-inch U gauge with water can be used. In wells from four to fifteen million feet, use mercury in a 12-inch U gauge, from fifteen to thirty-five million feet use a 50-pound spring gauge. Above thirty-five million feet use a 100-pound spring gauge. These foregoing figures are all based on a 6-inch hole.

For convenience, a scale graduated from the center in inches and tenths is attached between the two limbs of the U gauge. The distance above and below this center line at which the liquid stands in the gauge should be added, the object being to determine the exact distance between the high and the low side of the fluid in inches and tenths of inches.

The top joint of tubing or casing should be free from fittings for a distance of ten feet below the mouth of the well where the test is made. The test should not be made in a collar or gate or at the mouth of any fitting. The well should be blown off for at least three hours prior to making the test.

Having ascertained the velocity pressure of the gas flowing from the well tubing in inches of water, inches of mercury or pounds per square inch, as outlined above, the corresponding flow is given in the following table. The quantities of gas stated in the table are based on 4-ounce pressure or 14.65 pounds per square inch absolute, 60 deg. fahr. flowing temperature, 60 deg. fahr. storage temperature, and 0.6 specific gravity (air being 1.00). If the specific gravity is other than 0.6 the flow should be multiplied by

$$\sqrt{\frac{0.6}{\text{Sp.gr.of gas.}}}$$

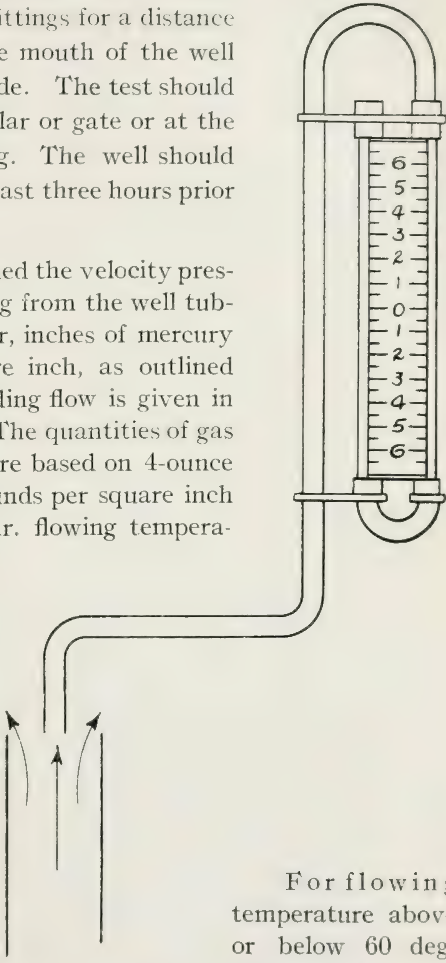


Fig. 60 — TESTING GAS WELL WITH A PITOT TUBE

For flowing temperature above or below 60 deg. fahr., deduct or add 1% for each ten degrees, respectively.

PITOT TUBE TABLE FOR TESTING OF GAS WELLS

TABLE No. 1—Discharge of Gas of 0.6 specific gravity from gas well tubing of different sizes in twenty-four hours.

(By F. H. Oliphant)

Pressure			Discharge in Cubic Feet			
In Inches of Water	In Inches of Mercury	In Lb. per Sq. Inch	1-inch Tubing	2-inch Tubing	3-inch Tubing	4-inch Tubing
.10			11,880	47,520	106,920	190,080
.20			17,136	68,544	154,224	274,176
.30			20,568	82,272	185,112	329,088
.40			23,520	94,080	211,680	376,320
.50			26,544	106,176	238,896	424,704
.60			29,112	116,448	262,008	465,792
.7			31,440	125,760	282,960	503,040
.8			33,624	134,496	302,616	537,984
.9			35,640	142,560	320,760	570,240
1.0			37,320	149,280	335,880	597,120
1.25			41,712	166,848	375,408	667,392
1.5			45,960	183,840	413,640	735,360
1.75	.12		49,680	198,720	447,120	794,880
2.0	.147		53,136	212,544	478,224	850,176
2.5	.184		59,400	237,600	534,600	950,400
3.0	.22	.108	65,088	260,352	585,792	1,041,408
3.5	.257	.126	70,272	281,088	632,448	1,124,352
4.0	.294	.144	75,120	300,480	676,080	1,201,920
4.5	.331	.162	79,704	318,810	717,336	1,275,264
5.0	.368	.18	84,000	336,000	756,000	1,344,000
6.	.441	.216	92,016	368,060	828,144	1,472,256
7.	.515	.252	99,360	397,440	894,240	1,589,760
8.	.588	.288	106,272	425,088	956,448	1,700,352
9.	.662	.324	112,656	450,624	1,013,904	1,802,496
10.	.736	.36	118,800	475,200	1,069,200	1,900,800
11.	.8	.396	125,160	500,640	1,126,440	2,002,560
12.	.88	.432	130,128	520,512	1,171,152	2,082,048
	1.02	.5	138,960	555,840	1,250,640	2,223,360
	1.52	.75	170,280	681,120	1,532,520	2,724,480
	2.03	1.00	196,680	786,720	1,770,120	3,146,880
	2.54	1.25	219,960	879,840	1,979,640	3,519,360
	3.05	1.5	240,720	962,880	2,166,480	3,851,520
	3.56	1.75	259,920	1,039,680	2,339,280	4,158,720
	4.07	2.00	272,640	1,090,560	2,453,760	4,362,240
	4.57	2.25	294,600	1,178,400	2,651,400	4,713,600
	5.08	2.50	310,800	1,243,200	2,797,200	4,972,800
	5.59	2.75	321,000	1,284,000	2,889,000	5,136,000
	6.10	3.	340,200	1,360,800	3,061,800	5,443,200

PITOT TUBE TABLE—*(Continued)*

Pressure			Discharge in Cubic Feet			
In Inches of Water	In Inches of Mercury	In Lb. per Sq. Inch	1-inch Tubing	2-inch Tubing	3-inch Tubing	4-inch Tubing
	6.61	3.25	354,120	1,416,480	3,187,080	5,665,920
	7.11	3.50	367,680	1,470,720	3,309,120	5,882,880
	7.62	3.75	380,400	1,521,600	3,423,600	6,086,400
	8.13	4.00	392,880	1,571,520	3,535,920	6,286,080
	8.64	4.25	405,000	1,620,000	3,645,000	6,480,000
	9.15	4.50	416,640	1,666,560	3,749,760	6,666,240
	9.65	4.75	428,280	1,713,120	3,854,520	6,852,480
	10.16	5.00	439,920	1,759,680	3,959,280	7,038,720
	12.20	6.	476,040	1,904,160	4,284,360	7,616,640
		7.	517,320	2,069,280	4,655,880	8,277,120
		8.	542,400	2,169,600	4,881,600	8,678,400
		9.	569,640	2,278,650	5,126,760	9,114,240
		10.	595,560	2,382,240	5,360,040	9,528,960
		11.	621,960	2,487,840	5,597,640	9,951,360
		12.	642,600	2,570,400	5,783,400	10,281,600
		13.	664,680	2,658,720	5,982,120	10,634,880
		14.	683,880	2,735,520	6,154,920	10,942,080
		15.	703,080	2,812,320	6,327,720	11,249,280
		16.	721,080	2,884,320	6,489,720	11,537,280
		17.	738,120	2,952,480	6,643,080	11,809,920
		18.	753,960	3,015,840	6,785,640	12,063,360
		20.	785,520	3,142,080	7,069,680	12,568,320
		22.	803,280	3,213,120	7,229,520	12,852,480
		25.	854,880	3,419,520	7,693,920	13,678,080
		30.	910,680	3,642,720	8,196,120	14,570,880
		35.	960,960	3,843,840	8,648,640	15,375,360
		40.	1,006,680	4,026,720	9,060,120	16,106,880
		45.	1,046,520	4,186,080	9,418,680	16,744,320
		50.	1,081,920	4,327,680	9,737,280	17,310,720
		60.	1,137,120	4,548,480	10,234,080	18,193,920
		75.	1,223,400	4,893,600	11,010,600	19,574,400
		90.	1,304,400	5,217,600	11,739,600	20,870,400
		100.	1,336,920	5,347,680	12,032,280	21,390,720

Table No. 2—Multipliers for pipe diameters other than given in the above tables. For any different sized pipe apply the multiplier to the figures given in the above table for "one inch tubing."

1½-inch = 2.25	5 -inch = 25.	8 -inch = 64.
2½-inch = 6.25	5⅝-inch = 31.64	8¼-inch = 68.
4¼-inch = 18.	6 -inch = 36.	9 -inch = 81.
4⅝-inch = 21.39	6¼-inch = 39.	10 -inch = 100.
	6⅝-inch = 43.9	12 -inch = 144.

Minute Pressure Testing of Gas Wells—It has often been the practice to measure the capacity of natural gas wells by quickly shutting a gate or valve and noting the pressure on a gauge at the end of each minute. Usually the pressure at the end of the first minute is used to approximate the volume.

Before making this test the well should be blown off for at least three hours.

The following table gives the volume in different sized tubing in lengths of 100 feet, which is followed by a table of multipliers for different pressures for one minute and for twenty-four hours.

Fig. 61.

VOLUME OF TUBING

Table Number 1

Diameter of Tubing in Inches	Volume in Cu. Ft. of 100 Feet of Tubing	Diameter of Tubing in Inches	Volume in Cu. Ft. of 100 Feet of Tubing
1	0.55	5⅝	17.26
2	2.18	6	19.63
3	4.91	6¼	21.31
3¼	5.76	6⅝	23.94
4	8.73	7¼	28.67
4¼	9.85	8	34.91
5	13.64	8¼	37.12
5³⁄₁₆	14.14	9⅝	50.53
5¼	15.03	10	54.54

The best gas well is one which, at the highest pressure, will discharge the greatest quantity of gas. The working capacity of any well can be tested by closing in the pressure by a gate at a length of half a joint or more of pipe from the open end. A gauge connected by a small pipe back of the gate will record the increased pressure. The flow can thus be measured at various back pressures by testing the open flow with a pitot tube as the pressure inside the well is increased.

MINUTE PRESSURE OF GAS WELLS

TABLE NUMBER 2

Opposite the gauge pressure are found the multipliers for one minute and for twenty-four hours. All figures are given at 14.65 pounds, or atmospheric pressure 14.4 pounds plus .25 pounds (4-ounce basis). Specific gravity of gas 0.6. Temperature 60 deg. fahr.

Gauge Pressure	Multipliers		Gauge Pressure	Multipliers	
Pounds	For One Minute	For 24 Hours	Pounds	For One Minute	For 24 Hours
1	.051	73	80	5.443	7837
2	.119	171	90	6.126	8821
3	.187	269	100	6.808	9803
4	.255	367	110	7.491	10787
5	.324	466	120	8.174	11770
6	.392	564	130	8.856	12752
7	.460	662	140	9.539	13736
8	.529	761	150	10.221	14718
9	.597	859	160	10.904	15701
10	.665	957	170	11.587	16685
11	.733	1055	180	12.269	17667
12	.802	1154	190	12.952	18650
13	.870	1252	200	13.634	19632
14	.938	1350	210	14.317	20616
15	1.006	1448	220	15.000	21600
16	1.075	1548	230	15.682	22582
17	1.143	1645	240	16.365	23565
18	1.211	1743	250	17.047	24547
19	1.279	1841	260	17.730	25531
20	1.348	1941	270	18.412	26513
21	1.416	2039	280	19.095	27496
22	1.484	2136	290	19.778	28480
23	1.552	2234	300	20.460	29462
24	1.621	2334	310	21.143	30445
25	1.689	2432	320	21.825	31428
26	1.757	2530	330	22.508	32411
27	1.825	2628	340	23.191	33395
28	1.894	2727	350	23.873	34377
29	1.962	2825	360	24.556	35360
30	2.030	2923	370	25.238	36342
35	2.372	3415	380	25.921	37326
40	2.713	3906	390	26.604	38309
45	3.054	4397	400	27.286	39291
50	3.395	4888	410	27.969	40275
60	4.078	5872	420	28.651	41257
70	4.761	6855	430	29.334	42240

Gauge Pressure	Multipliers		Gauge Pressure	Multipliers	
Pounds	For One Minute	For 24 Hours	Pounds	For One Minute	For 24 Hours
440	30.017	43224	530	36.160	52070
450	30.699	44206	540	36.843	53053
460	31.382	45190	550	37.525	54036
470	32.064	46172	560	38.208	55019
480	32.747	47155	570	38.890	56001
490	33.430	48139	580	39.573	56985
500	34.112	49121	590	40.255	57967
510	34.795	50104	600	40.938	58950
520	35.477	51086			

Example—Suppose that a well showed 320 lb. gauge pressure in one minute, and 2-inch tubing, the depth of the well being 1250 feet. From the first table the volume of 100 feet of 2-inch tubing is 2.18 cubic feet; and 1250 feet will have a volume of 12.5 times 2.18 or 27.25 cubic feet. From the second table the multiplier for one minute corresponding to the minute pressure of 320 lb. is 21.825. Hence the capacity of the well is 27.25 multiplied by 21.825, or 594.73 cubic feet per minute, 35.683 cubic feet per hour, 856,000 cubic feet per day. The daily capacity can likewise be determined directly by using the multiplier for 24 hours, corresponding to 320 lb. minute pressure, or 27.25 multiplied by 31,428 or 856,000 cubic feet per day.

If the packer is set up from the bottom, an addition will have to be made because of the additional space between the outside of the tubing and the wall of the well. Say that the packer is set up 120 feet in a hole 5⅝ inches in diameter. Then 17.26 minus 2.18 equals 15.08, the volume around the outside of the tubing per hundred feet of depth. Then the total volume around the tubing under the packer is 15.08

times 1.20, which equals 18.10 cubic feet. The volume of the tubing is 27.25 cubic feet, as previously determined; and the total volume of the well is 18.10 plus 27.25 which equals 45.35 cubic feet. 45.35×21.825 equals 990.0 cubic feet per minute, 59,400 cubic feet per hour, 1,425,000 cubic feet per day.

Fig. 62—A GOOD ADVERTISEMENT
Introduction of Natural Gas into Marshall, Texas.

This method is only a comparison of the value of wells and gives results considerably under the measurement of the open flow, which is the proper method of measuring the output. Both of these methods should be accompanied by the maximum rock pressure. The best well is the one which will discharge the largest quantity of natural gas at the highest pressure.

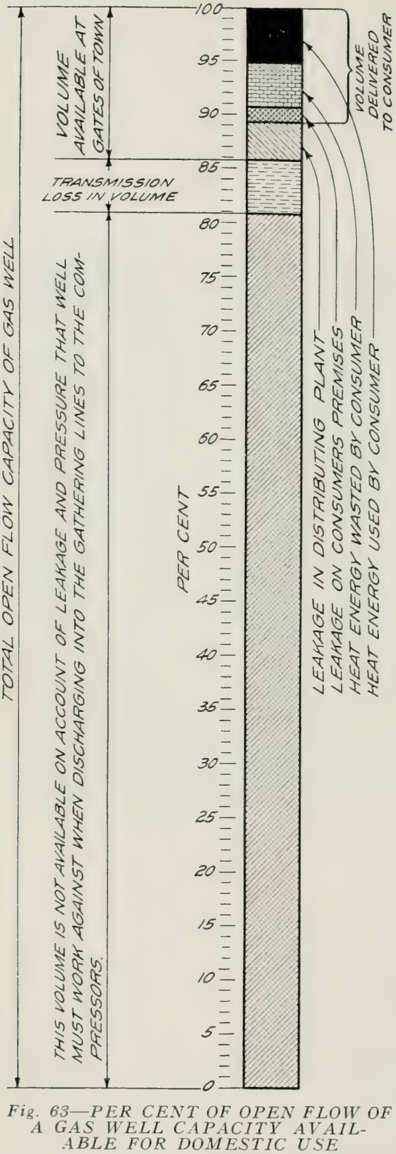


Fig. 63—PER CENT OF OPEN FLOW OF A GAS WELL CAPACITY AVAILABLE FOR DOMESTIC USE
By S. S. Wyer, in Natural Gas Service

Open Flow Capacities of Gas Wells—Unfortunately the well capacities that are generally reported by the newspapers and represented to gullible investors are the open flow capacities when the wells are discharging freely into the atmosphere. These open flow capacities are very much larger than the actual delivering capacities under routine operating conditions, as shown at the left. The data shown in this illustration were obtained by first determining the open flow capacities of representative wells and then passing the gas from these wells through meters, noting the amount that was actually delivered to the gas compressors.

It is also important to note that even after the gas reaches the consumer's premises much is lost, due to leakage and ineffective methods for utilizing the gas.

Rock Pressure—Rock pressure means the highest pressure attained in a gas well after being shut in for a period of 24 hours or longer. It is no indication of the size of the well.

The greater the rock pressure, the greater the distance the flow of a gas well can be transported without the assistance of a compressor.

As the gas is withdrawn from the pool, the rock pressure gradually declines until it finally becomes necessary to install compressors to raise the pressure in the lines sufficiently high to transport the gas to the market.

Working Capacity of Gas Wells Under Pressure—The following table show the approximate amount of gas a well will deliver into a pipe line under different back line pressures when the rock pressure and the open flow of the wells, found by the pitot tube, are given.

In taking the pitot tube test, the well should be "blown off" for at least three hours prior to test. Due allowance is made for conserving the well and keeping the pressure high enough to prevent water coming in on the sand. The porosity of the different sands, and the depth of the different wells are taken into consideration.

These tables are also based on the assumption that there is no lead between the well and the main line. Where lead lines are of any great length it will be found that the pressure at the main line will be less than at the well end of the lead line when the well is turned into the line. In this case the back pressure at the well end of the lead line is the pressure to be considered.

All capacities are given in cubic feet on a four-ounce basis for twenty-four hour periods.

FLOW IN 1000 CUBIC FEET FROM GAS WELLS AGAINST DIFFERENT LINE PRESSURES, ASSUMING THE ACTUAL OPEN FLOW CAPACITY OF THE WELLS TO BE ONE MILLION FEET DAILY

Back or Line Pressures Lb. per sq. in. Gauge	Full Rock Pressures (Lb. per sq. in. gauge) 100	150	200	250	300	350	400	500	600	700	800	900	1000
25	800	895	930	950	961	969	973	981	986	989	990	991	992
50	425	688	800	860	895	915	930	950	961	969	973	978	981
75	111	425	606	737	800	844	874	910	930	947	954	961	966
100	...	191	425	583	688	755	800	860	895	915	930	941	950
125	...	54	240	425	557	651	719	801	851	881	904	919	929
150	...	...	111	272	425	540	606	737	800	844	874	895	910
200	...	...	...	74	191	313	425	583	688	755	800	835	860
250	...	...	...	...	54	143	240	425	557	651	719	765	801
300	...	...	...	...	...	41	111	272	425	540	606	688	737
350	...	...	...	...	...	...	33	157	297	425	525	600	660
400	...	...	...	...	...	...	...	74	191	313	425	512	583
450	...	...	...	...	...	...	...	23	111	218	318	425	504
500	...	...	...	...	...	...	...	...	54	143	240	339	425
550	...	...	...	...	...	...	...	...	18	84	168	258	348
600	...	...	...	...	...	...	...	...	...	41	111	191	272
650	...	...	...	...	...	...	...	...	...	13	65	135	209
700	...	...	...	...	...	...	...	...	...	...	33	90	157
750	...	...	...	...	...	...	...	...	...	...	11	54	111
800	...	...	...	...	...	...	...	...	...	...	...	28	74
850	...	...	...	...	...	...	...	...	...	...	...	10	44
900	...	...	...	...	...	...	...	...	...	...	...	...	23
950	...	...	...	...	...	...	...	...	...	...	...	...	8

PART FIVE

Pipe Line Construction

SURVEYING—CONSTRUCTION CAMP—DITCHING —BLASTING AND SHOOTING—SCREW PIPE LINE (*Section*)—PLAIN END PIPE LINE (*Section*) —PIPE LINE WORK (*Section*).

Surveying—In constructing a long gas line, a survey should be made, using 3-foot stakes driven into the ground every two hundred feet, each stake being numbered with even numbers from the starting point. In short lines that follow highways the measuring can be done with an automobile speedometer, or with a bicycle and cyclometer. If neither of these is available, tie a cord or piece of cloth on one of the spokes in the front wheel of an ordinary buckboard and count the revolutions while driving over the route the line is to follow. The revolutions of the wheel, multiplied by its circumference, will then give the distance traversed by the vehicle.

Construction Camp—It is very essential in building a camp outfit to make bunks, floorings, etc., so that they may be readily removed from one location to another. The regulation size tent is 28 feet by 14 feet and will accommodate sixteen to eighteen men. Folding cots are convenient to use.

The men employed in camp are as follows:—cook, flunkies (one flunkey to every thirty men) and one night watchman. It is the duty of the night watchman to pack the buckets for the following day.

A No. 11 blanket and a 72-inch by 50-inch comforter should be used.

The charge for board for men is usually deducted from their wages.

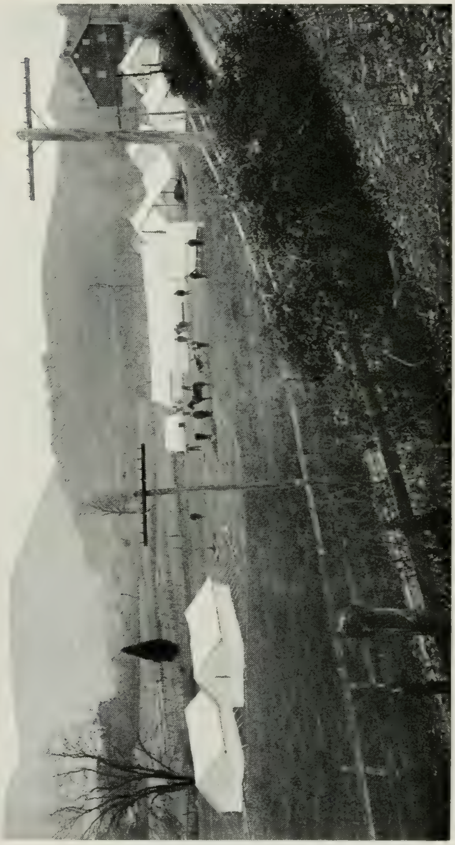


Fig. 64

Construction Camp in use while laying a 12 inch line from Thomas, W. Va., to Cumberland, Md.
Note—The two tents at the left were used by foreigners.

Ditching—The size of the ditch for different size gas lines is as follows:

Size of Pipe	Depth in Inches	Width in Inches
3- and 4-inch	20	Shovel
6-inch	24	Width
8-inch	28	20
10-inch	30	22
12-inch	32	24
16-inch	36	26

In constructing a line through timber, the right of way should be cleared sixteen to twenty feet in width.

Allow for wagon track on one side of the location of the ditch. In ditching on side hills throw the dirt on the lower side.

Fig. 65—DITCHING MACHINE AT WORK FOR A HIGH PRESSURE GAS LINE

Between Dennison and Petrolia, Texas, for the North Texas Gas Company.

The ditchers should be followed by the grading gang composed of from three to ten men. Their work is to straighten out, level and prepare the ditch for the tong gang.

Where it is not necessary to lay the line deep, as in the case of small lines, a large plow can be used. It is also often used in starting ditches for large lines.

Blasting and Shooting—In shooting use thirty per cent dynamite. "Dobie" shooting is commonly practiced and consists in placing the dynamite on top of the rock, and covering it with mud. Dynamite should be thawed by placing near a fire and turning frequently. It should be thawed very gradually. In drilling for shots use 5 to 8

Fig. 66—DITCHING MACHINE AT WORK FOR A 16-INCH LINE
Between Petrolia and Dallas, Texas, for the Lone Star Gas Company

pound sledges or hammers. The drills should be 12, 18, 24, and 30 inches long, of 1¼-inch diameter.

Each shooting gang consists of three men called strikers. The shooting gang should be accompanied by a blacksmith and helper with a portable forge.

To Prepare a Shot—Cut open one stick of dynamite and insert the percussion cap on the end of a fuse, placing the fuse in the center of the stick and closing the stick together. Insert the dynamite in the shot hole, packing gently with a wooden stick and fill on top with mud.

The fuse should project twelve to eighteen inches from the hole where the shot is placed. Size of shot varies according to the character of the rock; generally from two to three sticks to a shot.

SCREW PIPE LINE

Pipe Unloading—In loading and unloading either screw or plain end pipe, great care should be used to protect the end of the pipe. Pipe should not be thrown off the car onto the ground or pile, but should be rolled off on skids. In unloading 10-inch or larger, a mast and tackle block with one horse for power should be used. The method of taking hold of the pipe is by means of a rope loop with two iron hooks to hook into the opposite ends of the pipe.

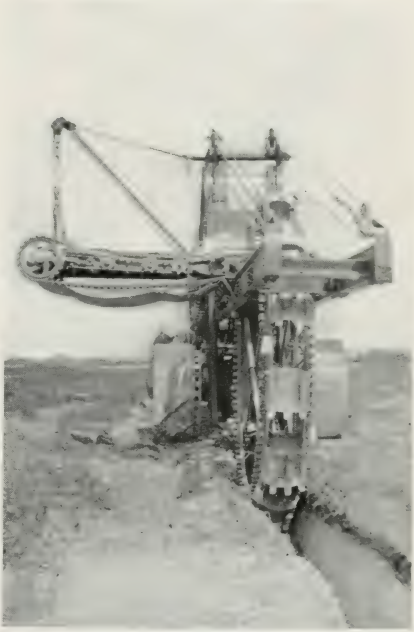


Fig. 67—REAR VIEW OF DITCHING MACHINE AT WORK

Tallying—All pipe should be tallied or measured when unloaded from the car. In measuring plain end pipe, measure the full length, while in measuring screw pipe, measure from thread end to center of collar.

Hauling—In the construction of large size lines, pipe is generally hauled under contract by the foot or by the joint.

All pipe should be carefully examined and defective joints thrown out before hauling to the right of way.

STANDARD DIMENSIONS, CAPACITY AND WEIGHT OF WROUGHT IRON PIPE FOR STEAM, GAS, OIL OR WATER

Diameters, Inches			Thickness of Pipe Inch	Outside Diameter of Coup'gs Inches	Feet of Pipe for 1 Cu.Ft. Volume	Weight of Pipe per Ft. Pounds	No. of Threads per Inch
Nom. Inside	Actual Inside	Actual Outside					
1/8	.270	.405	.068	.510	2500.	.243	27
1/4	.364	.54	.086	.720	1385.	.422	18
3/8	.494	.675	.091	.844	751.5	.561	18
1/2	.623	.84	.109	1.156	472.4	.845	14
3/4	.824	1.05	.113	1.375	270.	1.126	14
1	1.048	1.315	.134	1.625	166.9	1.670	11½
1¼	1.380	1.66	.140	2.125	96.25	2.258	11½
1½	1.611	1.9	.145	2.375	70.65	2.694	11½
2	2.067	2.375	.154	2.937	42.36	3.667	11½
2½	2.468	2.875	.204	3.500	30.11	5.773	8
3	3.067	3.5	.217	4.062	19.49	7.547	8
3½	3.548	4.	.226	4.687	14.56	9.055	8
4	4.026	4.5	.237	5.187	11.31	10.728	8
4½	4.508	5.	.247	5.750	9.03	12.492	8
5	5.045	5.563	.259	6.343	7.20	14.564	8
6	6.065	6.625	.280	7.343	4.98	18.767	8
7	7.023	7.625	.301	8.437	3.72	23.410	8
8	7.982	8.625	.322	9.375	2.88	28.348	8
9	9.001	9.688	.344	10.560	2.26	34.077	8
10	10.019	10.75	.366	11.680	1.80	40.641	8
12	12.000	12.75	.375	13.930	1.27	49.000	8

Where second-hand pipe is to be laid, its threads should be oiled and brushed with a wire brush.

Stringing—In stringing screw pipe, lay collar end in opposite direction from tong gang or starting point and allow for threads.

In placing large size pipe along the ditch in a rough country, a small stone boat or two-wheeled cart with a horse is used. In the former method, chain pipe to the boat and place a wooden plug in the head end of the pipe, to keep out dirt or snow when dragging.

STANDARD LINE PIPE

Nominal Inside Diameter Inches	Actual Outside Diameter Inches	Nominal Thickness Inches	Nominal Weight per Foot Pounds	Number of Threads per Inch of Screw
2	2.375	.154	3.609	11½
2½	2.875	.204	5.739	8
3	3.5	.217	7.536	8
3½	4.	.226	9.001	8
4	4.5	.237	10.665	8
4½	5.	.246	12.49	8
5	5.563	.259	14.502	8
6	6.625	.28	18.762	8
7	7.625	.301	23.271	8
8	8.625	.281	25.00	8
8	8.625	.322	28.177	8
9	9.625	.344	33.701	8
10	10.75	.2865	32.00	8
10	10.75	.3145	35.00	8
10	10.75	.366	40.065	8
12	12.75	.340	45.00	8
12	12.75	.375	48.985	8

Swabbing—All pipe should be "swabbed" out before laying. This should be done just ahead of the tong gang or just before the pipe is laid.

Fig. 68—SWAB

For a swab use one long joint of ¾-inch pipe as a handle having a leather disc, the same size as the internal diameter of the pipe to be swabbed or cleaned, clamped between two iron washers of slightly smaller size, attached to it.

Laying—The work of the tong gang consists of laying, painting, and inspecting for leaks, and in large size screw-pipe, bending. The number of men in a gang depends entirely on the size of the pipe. A tong gang for 8-inch pipe would be made up as follows:—one boss, one stabber, two jackmen, one "back-up" man, one "dope" man, and sixteen tong men.

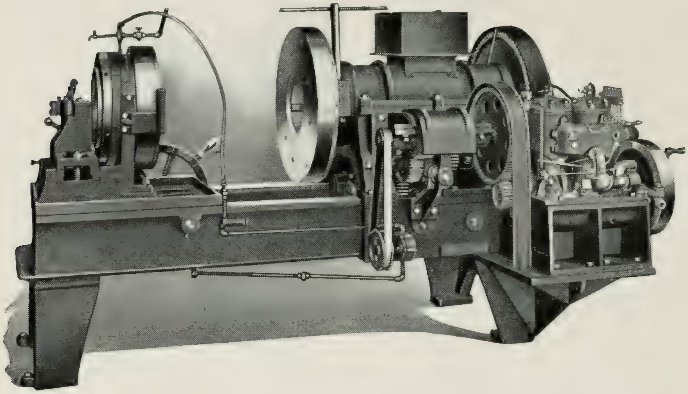


Fig. 69—PIPE CUTTING AND THREADING MACHINE WITH GAS OR GASOLINE ENGINE ATTACHED

Fig. 70—CARRYING BAR

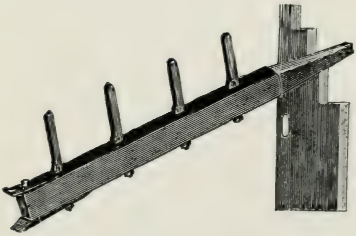


Fig. 71—PIPE JACK AND BOARD

Fig. 72—CARRYING TONGS OR CALIPERS

It takes four men to each pair of tongs. The man working on the end of the tongs occupies the position called "points" and is No. 1. The man nearest the pipe is called the "stroke" and is No. 4; the two men in between, Nos. 2 and 3. The tongs themselves are numbered likewise from 1 to 4, beginning with the pair of tongs nearest the "back-ups."

The stabber is the next most important man under the tong boss. His duty is to steer the pipe when it is inserted in the collar and see that the threads are not crossed prior to giving the pipe the first few turns with a common snubbing rope. The jackmen place the jack in position to support the pipe as the stabber directs. It is the duty of the "back-up" men to place the "back-up" tongs on the joint of pipe previously set up to prevent it from turning.

A 2-pound hammer is used by the tong boss or stabber in striking the collars into which the pipe is being screwed, the idea being to jar the collar as the tongs start on the downward stroke and assist in setting up the joint. Carrying irons or calipers are used to carry large-size pipe from side of ditch to position for stabbing. The "dope" man carries the asphaltum or "dope" and paints the collar threads just ahead of the tong gang.

For letting the pipe into the ditch after it has been set up, a wooden horse, built so that the legs will stand on either side of the ditch, and a snubbing rope are used. Only one wooden horse is necessary. The pipe is let down

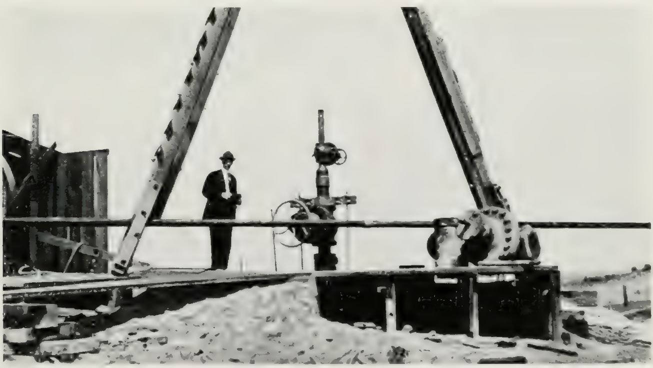


Fig. 73—GAS WELL IN THE MIDWAY, CALIF., FIELD

on the "growler board" which is placed under the collar of the joint just set up, to support the pipe above the ditch until the wooden horse can be moved ahead to a new position.

Painting—All pipe laid under ground should be painted, especially when second-hand casing is used for a gas line. Use a regular small-size "hot tar cart." The tar should be kept hot and put on the pipe with a brush swab after the pipe is set up and before it is lowered into the ditch.

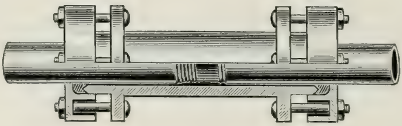


Fig. 74—EXPANSION SLEEVES

Laying Pipe in Level Country—In laying large-size high pressure pipe lines in level country use an expansion sleeve every mile or two. In case the line makes an abrupt angle, the tee should be anchored with a large rock or concrete bumper. This will prevent the line parting at the nearest sleeve.

Laying Pipe in Rough Country—Lay lines deep through any knoll or ridge, or, in other words, lay it as straight as possible with no more fire bends than are absolutely necessary. On steep inclines, put in "deadmen," or anchorages, the size and number depending upon the steepness and length of the incline. Also place bunches of underbrush, with branches pointing up hill,every fifty feet in the ditch and fill in on top of the brush. The underbrush prevents washouts. Do not lay lines through "slips" or where there is any possibility of a "slip" in the future.

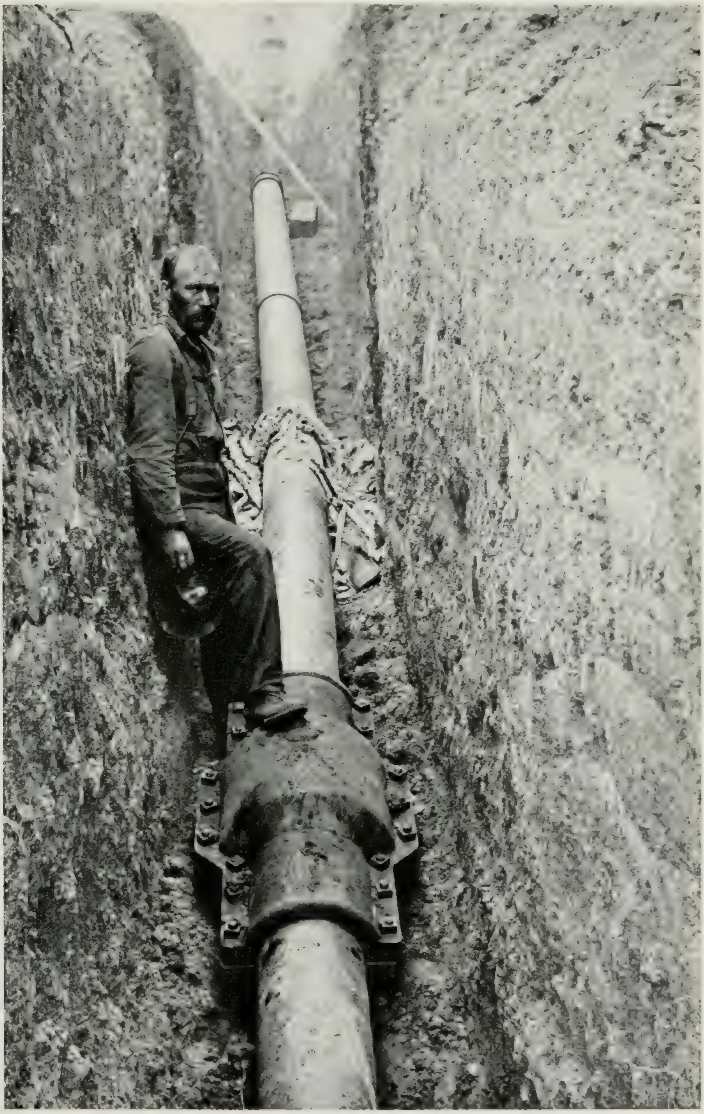


Fig 75—PIPE LINE ON RIVER BANK AT POINT OF LEAVING RIVER BED
Note heavy cast iron river clamp and remains of fire where fire bend was made.

Bending Screw Pipe—To make an under or sag bend, set up one or two joints beyond the point to be bent, supporting the end above the ditch. Build a fire of wood (using some kerosene), about three feet long, covering the point to be bent on both sides of the pipe. The fire can be built underneath the pipe in the ditch or, in case the pipe

Fig. 76—RIVER CROSSING SHOWING TRIPLE LINES

is above the ditch, use a couple of hangers, with a sheet of iron suspended under the pipe where bend is to come and build the fire on this. After being properly heated, bend the pipe by the weight of men. Care should be used that the pipe is not burned or buckled.

For over-bends, make a sag bend as above described and screw joint of pipe one-half turn to bring the bend on top.

Rivers and Creeks—In laying lines through small rivers or creeks where the water contains injurious chemicals, the pipe should be encased in concrete. In crossing a river

Fig. 77—LAYING 12" HIGH PRESSURE LINE ACROSS TYGARTS VALLEY RIVER, NEAR BELINGTON, WEST VIRGINIA

Fig. 78—LAYING 12" HIGH PRESSURE LINE ACROSS A RIVER SHOWING COFFER DAM TO KEEP OUT WATER WHILE LINE IS LAID IN CONCRETE

where concrete is not necessary, each joint of pipe should be weighted down with a cast iron clamp at the collar, as the pipe will float unless anchored. River "dogs" or hooks may also be used for anchoring the pipe.

Fig. 79—HIGH PRESSURE GAS LINE ACROSS TRINITY RIVER NEAR DALLAS, TEXAS.

Note preparation for making fire bend.

In laying gas lines across shallow rivers or creeks where the lines are not cemented, they should be buried if possible and well covered with rock.

Railroad Crossings—Where gas lines cross under railroad tracks, they should be run through a casing which should extend a few feet from either side of the track. This acts as a protection against the jar of passing trains, and in event of any leakage it carries the gas off to the side of the track.

Small Gas Lines—With small-size screw pipe lines, lay "snake like" to allow for expansion and contraction, in which case expansion sleeves are not necessary. This method consists in laying the pipe in a wavy line to permit the expansion or contraction to be taken up by the bending of the pipe.

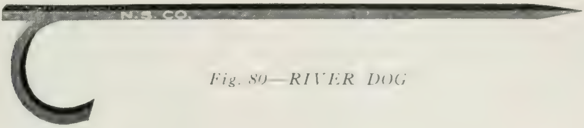


Fig. 80—RIVER DOG

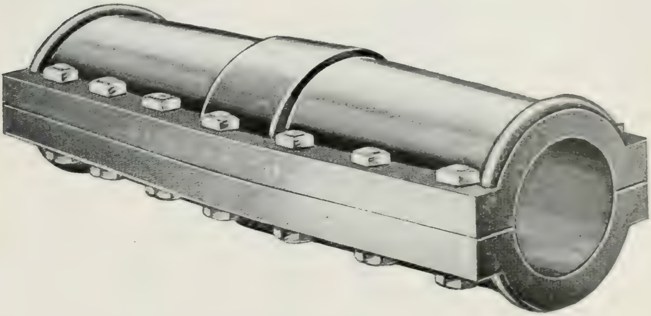


Fig. 81—CAST IRON RIVER CLAMPS
To prevent pipe joint breaking or leaking.

Fig. 82—HIGH PRESSURE GAS LINE ACROSS THE TRINITY RIVER
Near Dallas, Texas. Note the small gasoline engine and pump for keeping water out of ditch while line is being laid.

PLAIN END PIPE

Plain End Pipe—Plain end pipe is the same as screw pipe except that it has no threads. Including couplers, it is a

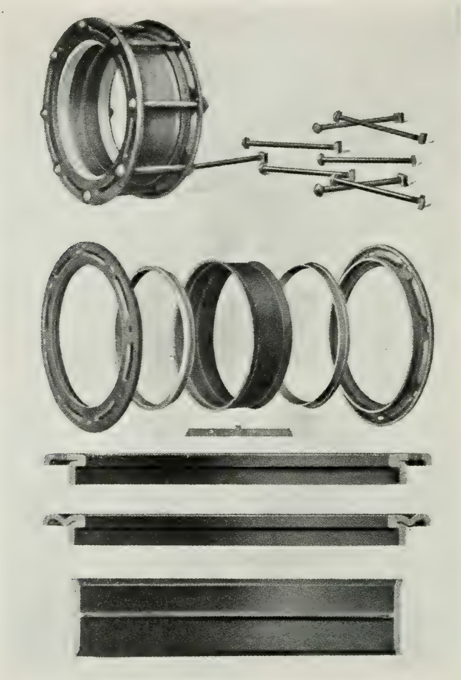


Fig. 83—PLAIN END PIPE COUPLING SHOWING PARTS AND SECTIONAL VIEW OF RINGS

little more expensive than screw pipe, although the cost of laying is less than that of screw pipe.

Hauling Plain End Pipe—In hauling plain end pipe, load one center ring and two end rings to each joint of pipe on the wagon. If the bolts are received in sacks, they should be distributed along the right of way according to the number required for each joint of pipe.

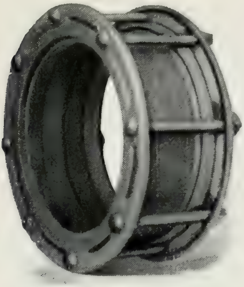


Fig. 84—PLAIN END PIPE COUPLING

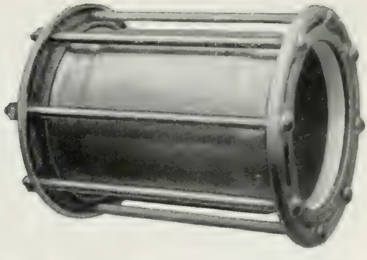


Fig. 85—ALL-STEEL LONG SLEEVES
Sizes: 10 inches inside diameter to 18 inches outside diameter, inclusive. 16 inches long.

Stringing—In stringing plain end pipe, lay same with ends butting together.

Bending—Bending plain end pipe should be done before the pipe is set up and ahead of the laying gang.

In making bends distribute the fire for a distance of about three feet on both sides of the pipe and do not place the center block too near the fire. Apply greatest heat on side of pipe that is intended to stretch. After being sufficiently heated the pipe should be bent gradually to prevent buckling. The boss of the bending gang should be a man of good judgment.

Fig. 86—MAKING FIRE BEND
Using pipe tongs and chain on a two-inch pipe as a windlass. Large pipe is chained together at opposite end and block is placed between the chained end and the fire.

Fig. 87—BENDING JOINT OF 16-IN. PIPE BY FIRE METHOD OR HEATING

Laying—The pipe is put together on skids laid across the ditch. After placing the end ring and rubber on the end of the pipe, stab the joint into the center ring until the end

Fig. 88—PLAIN END PIPE READY TO STAB

of the pipe butts the bead in the center of the center ring. The outside rings should be bolted together while the pipe rests on the skids over the ditch and inspected in this position. In bolting up center rings, bolt four bolts equally distant first. Care should be taken that the two outside rings are equally distant at every point around the center ring. After ten or twelve joints are thus connected, all but the last joint or two can be lowered in the ditch by the use of wooden horses and snubbing rope. Ratchet wrenches should be used to tighten bolts. The bolts should be placed in the end rings so that the nuts will come on the left hand side of the center ring on either side of the pipe. This will allow the wrencher to work right-handed and with downward stroke, regardless of which side of the pipe he is working on.

Fig. 89—STABBING PLAIN END PIPE

In laying over hills or through gulleys, where deep ditching is impossible and angles are not sharp enough to require bending or the use of angle joints, use short joints of pipe, making a slight angle at each joint.

Figs. 90 and 91—"WRENCHING UP" PLAIN END CENTER RINGS

Fig. 92—PLAIN END PIPE LINE COMPLETED
Ready to lower into ditch by use of wooden horses and snubbing rope.

Fig. 93 LOWERING COMPLETED PLAIN END PIPE LINE INTO THE DITCH BY USE OF WOODEN HORSES AND A SNUBBING ROPE

Creeks and Water-Soaked Ground—Where line crosses creeks and is not cemented, screw pipe should be laid, and the same methods should be followed as given under the subject of screw pipe.

Fig. 94.
PLAIN END PIPE LINE ON SIDE HILL
Showing Rock Fill to Prevent Washout and to Anchor Pipe.

Plain end pipe laid in swampy or water-soaked ground should be well anchored with rocks to prevent blow-outs.

Whenever it develops that a plain end pipe line has been laid through land that is liable to inundation or is very wet and swampy at certain times of the year, it is policy to lay out a new survey beginning at the high points at either end of the low ground, and if possible, run an extra line around on high ground to avoid any wash outs or interruptions in the service of the high pressure line.

Rough Country—Do not lay plain end pipe down hill. Always start at the foot of the hill and lay up.

Angle Couplings—In place of bending, angle couplings can be used to advantage but must be well anchored with rock.

Inspection and Leaks—One of the most important things to observe in the construction of a plain end pipe line, is the inspection of the couplings after being laid.

To repair leaks on plain end pipe under pressure, do not uncover more than one coupling at a time.

All center and end rings should be carefully inspected before laying.

Covering—The covering is done by a section of the ditching gang, after the pipe has been tested by the tong gang.

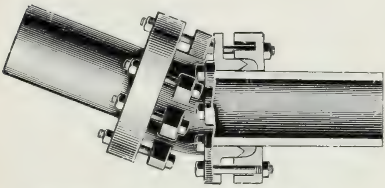


Fig. 95—ANGLE COUPLING

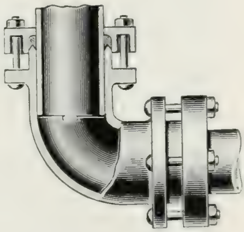


Fig. 96—90 DEG. ELL

Fig. 97—COVERING COMPLETED PIPE LINE
By Use of Team and Dirt Shovel.

Do not cover a pipe line with cinders on account of the sulphur in them, they will corrode or pit the pipe, and rapidly destroy it.

Fig. 98—BLOWING OUT 16-INCH GAS LINE BEFORE PLACING IN USE

Note the Anchorage or "Deadmen" to Prevent Line Pulling Apart on Account of Pressure on Line Before Completion.

PIPE LINE WORK

Inspection After Gas Line is Completed—After a gas line is completed and covered, attention should be given the work to note whether the filling has settled, or whether any washouts have occurred. The best time for making an inspection is directly following a hard rain.

A plain end pipe line under pressure requires a considerable amount of covering to prevent blow-outs.

Line Walking—After a large high pressure gas line has been put into service, a line-walker should be employed for each fifteen or twenty miles of pipe, and he should inspect his allotted section of line daily. A great many companies construct a telephone line along the right of way, placing telephone boxes, under lock and key, every five or ten miles. Boxes should also be placed at railroad and river crossings and at all points where slips are liable to occur.

If desired, installations can be made for telephone plugs, in which case the telephone stations can be placed about two miles apart. The line-walker then carries a portable telephone outfit that can be "plugged in" at each of the stations.

Line Loss Percentage—The question is often asked—"What percentage of loss should we have in our low pressure system, even though the gas line is tight and services and meters have been carefully inspected?"

This is rather a difficult question to answer with any degree of accuracy but approximately the loss will be from fifteen to twenty-five per cent.

It should be taken into consideration that a small leak on a gas line, even though it may be blown out by the use of a hat, means a continual loss of gas for not only twenty-four hours a day, but for three hundred and sixty-five days a year, and this so-called small leak will often supply a single consumer for a like period. Too much attention cannot be given

to these small details. The gas leaking into the atmosphere means a continual loss in money. The fact that natural gas is a product of nature is positively no reason why it should be allowed to escape, regardless of where the leak may be, whether at the wells, on a line, or in house piping. Constant inspection of high and low pressure gas systems and the stoppage of all leakage found is the one method of conservation that is successful.

High Pressure Pipe Line Leakage—The mere fact that one has walked the full length of a buried pipe line (even though the line is laid but three or four inches beneath the surface) and has found or heard no leaks, does not furnish conclusive evidence of a tight gas line.

In testing for leaks some men use a torch, made by tying a small bundle of waste to the end of a pole eight or ten feet long, saturating with kerosene, and carrying it lighted over the full length of the line, holding the flame close to the top of the covered ditch. This method has met with success in some cases and is perfectly safe to the employee unless some exceptionally large leaks are met with. But it is not absolutely positive, and should not be used where a line shortage of any serious nature has developed.

It is taken for granted, in covering this particular subject, that a pipe line has been carefully tested for leaks by allowing high pressure gas to remain in it over night before placing the line in actual service. It is not always necessary to uncover every joint after a line is laid and covered. One can find the leaks by driving a blunt-pointed bar at short intervals along the pipe line, and applying a torch to the hole made by the bar. In certain kinds of soil the leaking gas or heat of the sun often tends to form crust over a leaking joint, thereby forcing the leaking gas in different directions through the ground, and especially along the pipe, instead of directly to the surface. If, after driving the bar into the ground, the gas is found to burn at the openings made

by it, the exact location of the main leak can be determined by the comparative size of the flames at the openings. As the holes approach the main leak it will be noticed that the flames increase in size, thereby locating the point at which to make repairs. Oftentimes gas will travel along a pipe line many feet from the original point of leakage before coming to the surface.

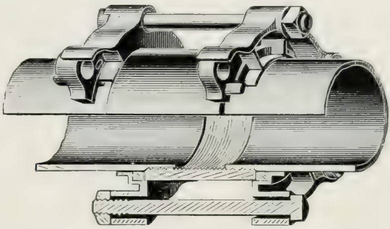


Fig. 99—COLLAR LEAK CLAMP

Certain kinds of soil, especially where cinders exist, have a chemical effect on the metal of the pipe, thereby causing the pitted effect commonly noticed. Cases have been known where pipe has been eaten through in a period of from one to two years time. If expansion sleeves are used in a pipe line and the line has any abrupt angles, unless the point at the angle is well anchored the expansion sleeves are apt to pull apart, due to the contraction of the pipe. It is well worth the cost and trouble to thoroughly inspect a high pressure gas line at least once or twice a year. By the above statement it is meant to make a bar test over the whole line for leaks.

Lines should be kept free from dirt, water or other foreign substances. This is generally done with the great majority of pipe lines, yet in some cases the regulators as well as the meters will show dirt and water, whereas if the line had been kept clean this would have been eliminated. While large capacity meters or regulators will take care of a fair per-

centage of dirt and water without effecting their usefulness, it is not intended that they should measure dirt and water with a small percentage of gas.

The leakage from a pipe line is independent of the quantity of gas being passed through the line but is wholly dependent upon the pressures existing in the line. It can therefore amount to a very high percentage of the gas passed, in the case of a small flow and a high pressure, or again the percentage loss may be quite low when the volume of the flow is large and the pressure low.

Do not test a pipe line with a combination of air and gas. The pumping of air into a pipe line while there is gas in the line is apt to form the proper mixture for an explosion. Pebbles or scale blown along a line may cause sparks and this mixture of gas and air ignited has blown up miles of line.

The higher the gas pressure in pipe lines, the more apt the line is to leak.

Water in Pipe Lines—It is not uncommon to find instances where a great deal of free water has been drawn from drips or taps along a high pressure gas line, whereas practically no free water passed through the regulator or meter at the well in the field. This is explained by the fact that all natural gas carries more or less aqueous vapor which will not condense at the meter or regulator unless the temperature conditions are right, but which will condense at different points along the line, thereby forming free water. One pound of water at 62 deg. fahr. will make 1153 cubic feet of aqueous vapor. While aqueous vapor should not account for any great loss in a measured volume of gas flowing between two points, there are cases where it should be taken into consideration, especially where there is a compressor. In the latter case a series of tanks or pipe returns are installed on

the outlet side of the compressor to cool the gas, as well as to take care of the condensation. The compressor, while increasing the pressure of the gas, necessarily raises the temperature to a high degree, and in cooling, the aqueous vapor condenses wherever coming in contact with the pipe, which is kept at a lower temperature than the gas by the temperature of the atmosphere or water surrounding the cooling system. In the latter case it has proven good practice to install the outlet lines from a compressor through a pond. This has the desired effect and decreases the amount of the pipe required.

Fires on High Pressure Gas Lines Due to Leaks or Blow-outs—Small-size fires can easily be put out by the use of a hand fire extinguisher. It is good policy for any gas company to have in an accessible location, a hand chemical cart holding at least twenty-five gallons. This size cart will extinguish a fire or blaze from twenty to twenty-five feet high. Another method commonly practiced is to pile stone on the fire until the pile is three or four feet high, then turn a stream of water onto the heated stone. The effect is to create steam which smothers the flame.

Break in High Pressure Gas Line—If a break occurs in a high pressure line and shuts off the gas in a low pressure system, all gates at low pressure regulating points should be closed and the break repaired, after which all consumers should be notified at what hour the gas will be turned on again. If the break occurs in the night, it is better to keep gas turned off until morning.

Fig. 100—Laying Temporary Pipe Line across Red River (Ark.), showing where Line leaves the new river bed

Fig. 101—Laying Temporary Line across the Red River (Ark.) In midstream Line was Floated on a Log Raft. The Water was 25 Feet Deep at that Point

Pipe Line Washout Across Red River (1915)—Figures Number 100 and 101 fully illustrate the laying of a temporary 10-inch line across a new river bed made by flood conditions, so common in the Southern Mid-Continent field. The pictures were taken at the pipe line crossing of Red River, near Garland City, Ark., of the Arkansas Natural Gas Company's main line from the Caddo field.

The break was caused by the river over-flowing its banks and creating a new river bed. In the overflow the original pipe line was washed out, with two additional temporary lines. To better describe the conditions directly following the first break in the line, the author quotes from the Superintendent's letter:

"There was no bank like an ordinary river or break. All we could do was to go up the river with our motor boat and barge and pile our material on top of the levee, where you could stand and look around in all directions and see nothing but water, from one to ten feet deep. This break occurred on a right angle bend in the river and when the levee let go, the river went right across the country. That is, it just divided at this point and continued to run out that way for ten or fifteen days after each rise in the river and the current was so swift it was impossible to undertake to go into the break with a boat or anything of that nature. The crevice in this levee where the water ran through was about 1,500 feet wide."

This is only one of the many obstacles encountered by the gas company in transporting gas from a field far remote from their market. No business is so fraught with unforseen contingencies as the natural gas business.

Blow-offs and Drips—Place blow-offs or drips on the main field line in the immediate vicinity of the field wherever there is a depression or gulley. The regulation gas well drip

Fig. 102—Automatic Drip for either High, Intermediate or Low Pressure Gas Line

Fig. 103—Water Flowing from Automatic Drip Shown in Fig. 102.

can be used to advantage. The drip should be placed a little ahead of and higher than the lowest point of the depression or gulley. These drips or blow-offs should be visited often and kept free from water.

Gas tanks can be used on a gas line in place of drips. These tanks are built in different sizes with a baffle plate in the center against which the gas from the inlet line strikes in entering the tank.

The liquid in the gas is caught on the plate and drops to the bottom of the tank, while the gas passes around the plate and out of the tank, freed from its liquid.

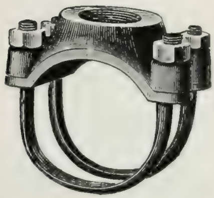


Fig. 104
HIGH PRESSURE PIPE LINE SADDLE
Note—Sheet Lead makes the best Gasket

High Pressure Taps—In making a high pressure tap, cut out a circle of the size desired on the pipe with a diamond point chisel; then strap on the saddle with the nipple and gate set up in saddle. The circle should be cut in the pipe until the gas begins to leak. After the saddle and connections are strapped on, the center of the circle can be punched through and the gate closed.

Section

Figs. 105 and 106 —CAST IRON GATE LOCKS

Gates and Fittings—Gates left unboxed should have the wheel removed.

Open high pressure gates slowly when under pressure.

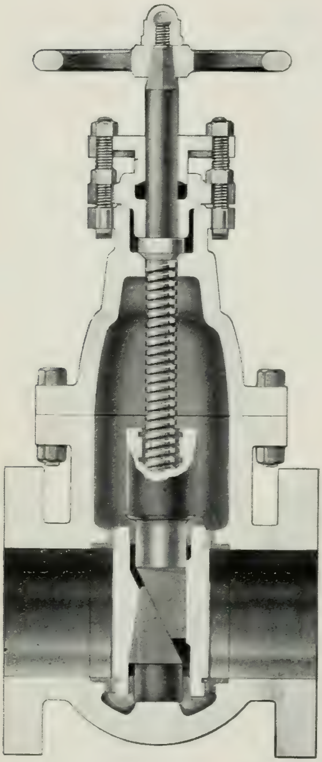


Fig. 107—SECTIONAL VIEW OF HIGH PRESSURE GATE VALVE

Use nothing but high pressure fittings on a high pressure gas line and do not use bushings.

The objections to using stop-cocks on high pressure gas lines is that the core of the stop will often become corroded and stick, requiring the jarring of the small end of the core in order to turn it. This is a dangerous practice, especially if there is any frost in the metal.

Common paste board or tar paper makes good gasket material for field use. In the event of a high pressure valve or stop-cock becoming coated with frost, do not attempt to knock the frost off with a hammer or wrench, but use warm water to thaw it.

Do not attempt to caulk fittings on a gas line under high pressure.

For splits in a gas line, use an extra heavy cast iron clamp with stuffing box. For leaks in thin collars, use collar leak clamps. Caulking the collars, as a rule, will not make a permanent tight joint on account of the expansion and contraction of the pipe.

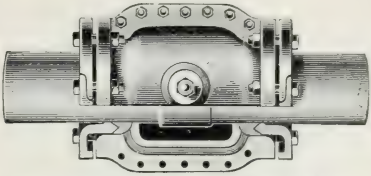


Fig. 108—HEAVY SPLIT SLEEVE
For Wrought Iron Pipe.

Gauges—In placing a high pressure gauge at a farm house or lease house, it should be mounted on the outside of the building so that it can be seen through the window. Do not place any high pressure lines on the inside of such a building.

Gauges should be tested at least twice a year, or oftener, when there is any reason to doubt their accuracy.

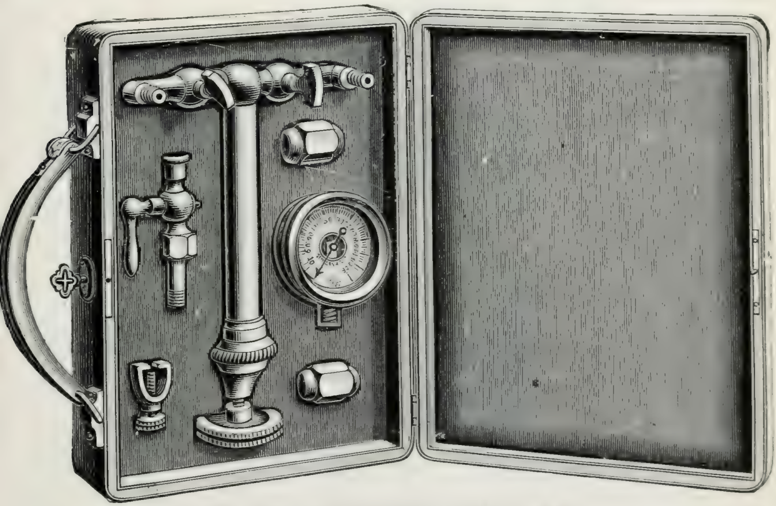


Fig. 109—INSPECTOR'S TEST PUMP
Can be used for any type of Indicating or Recording Spring Gauges.
Even though the hand on the gauge rests at zero when the gauge is not in use, it does not necessarily follow that the gauge would be accurate at higher pressures. Hence in testing gauges test at different pressures within the range of the gauge.

The outfit illustrated here can readily be used to check recording gauges.

This inspector's test pump is furnished complete in leather case, and weighs about eight pounds.

It is especially adapted for natural gas companies having high pressure gauges scattered over a wide territory.

House Regulators—For use at farm houses, lease houses, and on some high pressure lines where the consumers are widely separated, the house regulator is very necessary.

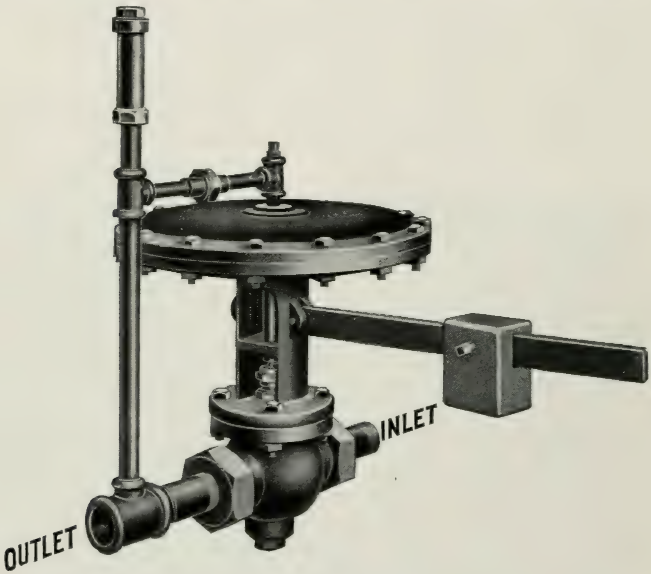


Fig. 110—DEAD WEIGHT TYPE OF HOUSE REGULATOR

It is essential to keep the regulator housed or well boxed to prevent children and animals interfering with it or injuring it. The writer has seen chickens roosting on the arm of the weight type of regulator while the consumer was complaining of its unsatisfactory work.

If a regulator freezes, thaw it with warm water.

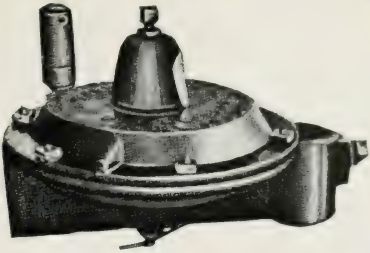


Fig. 111

SPRING TYPE OF HOUSE REGULATOR

For use on a high pressure line.

There are several types of house regulators, one of which is illustrated on page 220. These regulators are built with small needle-like valves and will reduce the gas from a pressure of several hundred pounds down to a few ounces.

Fig. 112—LAYING $6\frac{5}{8}$" HIGH PRESSURE GAS LINE ACROSS THE MIDDLE FORK RIVER, BARBOUR CO., W. VA.

Line is Being Laid in Bed of River.

PART SIX

Capacities of Pipe Lines

Friction—There is no actual loss of gas in a pipe line as the result of friction. The effect of the friction is merely to produce a drop of pressure.

Formulas for Pipe Line Capacities—No two pipe line formulas will check exactly with one another. They are intended only for practical purposes in determining the proper size of lines to carry a certain amount of gas, and not to check with a meter. So many different factors enter into the computations of pipe line flows as to prevent the use of the formula as a means of measuring with any degree of accuracy, and it is impossible to consider it as a check on the readings of a meter. No two pipe lines of the same nominal diameter and length are exactly alike when carefully calibrated, due to many causes, the principal one of which is that commercial pipe is not strictly of a uniform diameter, and accumulation of sediment and dirt will change not only the effective diameter of the pipe in varying amounts but also the co-efficient of friction of the flowing gas. Any deviation of the actual effective diameter from that assumed in using the formula results in a multiplied error in the computed flow, due to the fact that the flow is proportional to the diameter raised to the 2.542th power. Leakage varies in different lines due to different operating pressures, thus introducing a variable error, and it is seldom found that a condition of uniform flow obtains, which is assumed in the construction of all pipe line formulas. They should therefore be used only for determining the size of lines in designing pipe line systems, or for obtaining an idea of the pressures to be expected at various points under given flow conditions, or the approximate carrying capacity of the lines under given pressure conditions.

TABLES A, B, C AND D.

Tables to Find the Flow in Cubic Feet per Day of 24 Hours of Gas of 0.6 Specific Gravity with Different Pressure Conditions in Pipe Lines of Various Diameters and Lengths.

Select in Table A the resultant opposite the gauge pressure of the line the capacity of which is to be determined; then in Table B select the multiplier opposite the length of the line in miles. Multiply these two numbers. The result is the cubic feet a one-inch line will discharge for the pressure and length named in twenty-four hours. If the diameter of the pipe is other than one inch, select the multiplier in Table C which is shown opposite the diameter, and multiply this number by the discharge for one inch already determined. The result is the quantity in cubic feet discharged in twenty-four hours by a line of the diameter and length selected.

If the stated pressures and lengths are not given in the table they can be secured by interpolation.

Example—Suppose it is required to find the discharge per day of twenty-four hours of a pipe line having an intake of 200 lb. gauge pressure and 25 lb. at the discharge end, the length being twenty miles and the diameter eight inches. In Table A we find opposite 200 (the intake pressure) and 25 (the discharge pressure) the number 211.3 and in Table B, opposite 20 miles, 225.5. Multiplying these two numbers, the result—47,637 cubic feet—is the quantity that, under the above conditions of pressure and length, a one-inch pipe would convey. The given diameter is eight inches, however. Opposite this number in Table C it will be found that 198 is the proper multiplier; therefore 47,637 × 198 = 9,433,126 cubic feet discharged in twenty-four hours.

If the pressure were twenty pounds instead of twenty-five at the discharge end, the flow could be found very closely

TABLE A

(By F. H. Oliphant)

Intake Lb.	Discharge Lb.	Resultant	Intake Lb.	Discharge Lb.	Resultant	Intake Lb.	Discharge Lb.	Resultant
1	¼	4.7	15	6	21.4	60	25	63.4
1	½	3.9	15	9	18.0	60	30	60.0
2	½	6.9	15	12	13.1	60	40	51.0
2	1	4.7	20	1	31.1	60	50	37.4
2	1½	4.0	20	4	29.4	60	55	26.9
3	1	8.1	20	8	26.4	70	5	82.6
3	2	5.8	20	10	24.5	70	10	81.2
4	1	10.1	20	15	18.0	70	20	77.5
4	2	8.4	20	18	11.7	70	30	72.1
4	3	6.0	25	1	36.7	70	40	64.8
5	1	11.8	25	3	35.7	70	50	54.7
5	2	10.4	25	6	34.0	70	60	40.0
5	3	8.6	25	10	31.2	80	5	92.8
5	4	6.2	25	15	26.5	80	10	91.6
6	1	13.4	25	18	22.6	80	20	88.3
6	3	10.6	30	1	42.1	80	30	83.7
6	5	6.3	30	3	41.2	80	40	77.5
7	1	14.9	30	6	39.8	80	50	69.2
7	3	12.5	30	10	37.4	80	60	58.3
7	5	9.0	30	15	33.5	80	70	42.4
7	6	6.5	30	20	28.3	90	5	103.1
8	1	16.3	30	25	20.0	90	10	102.0
8	3	14.1	40	5	51.2	90	20	99.0
8	5	11.2	40	10	49.0	90	30	94.9
8	7	6.6	40	15	46.1	90	40	89.4
9	1	17.6	40	20	42.4	90	50	82.5
9	3	15.6	40	25	37.8	90	60	73.5
9	5	13.1	40	30	31.6	90	70	61.6
9	8	6.8	40	35	22.9	90	80	44.7
10	1	19.2	50	5	61.8	100	5	113.3
10	2	18.3	50	10	60.0	100	10	112.3
10	4	16.3	50	15	57.7	100	15	111.0
10	6	13.6	50	20	54.8	100	20	109.5
10	8	9.8	50	25	51.2	100	25	107.8
10	9	7.0	50	30	46.9	100	35	103.6
12	1	21.8	50	35	41.5	100	50	94.9
12	3	20.1	50	40	34.6	100	75	71.6
12	6	17.0	50	45	25.0	100	85	56.8
12	8	14.1	60	5	72.3	100	95	33.5
12	10	10.2	60	10	70.7	110	5	123.4
15	1	25.4	60	15	68.8	110	15	121.4
15	3	24.0	60	20	66.3	110	25	118.4

TABLE A *(Continued)*

Intake Lb.	Discharge Lb.	Resultant	Intake Lb.	Discharge Lb.	Resultant	Intake Lb.	Discharge Lb.	Resultant
110	35	114.6	200	125	163.2	275	100	266.2
110	50	106.8	200	150	137.9	275	150	238.5
110	75	86.8	200	175	100.6	275	200	194.6
110	85	75.0	200	190	64.8	275	250	117.8
110	100	49.0	220	5	234.2	300	5	314.4
125	5	138.6	220	15	233.1	300	15	313.6
125	15	136.8	220	25	231.6	300	25	312.5
125	25	134.2	220	35	229.6	300	35	311.0
125	35	130.8	220	50	225.8	300	50	308.2
125	50	124.0	220	75	217.1	300	75	301.9
125	75	107.2	220	100	204.9	300	100	293.3
125	100	79.8	220	125	188.8	300	125	282.2
125	110	63.1	220	150	167.3	300	150	268.3
135	5	148.7	220	175	138.3	300	175	251.3
135	15	147.0	220	200	94.9	300	200	230.2
135	25	144.6	230	5	244.1	300	250	170.3
135	35	141.4	230	15	243.2	300	275	123.0
135	50	135.2	230	25	241.7	325	5	339.4
135	75	120.0	230	35	239.8	325	15	338.7
135	100	96.3	230	50	236.2	325	25	337.6
150	5	163.8	230	75	227.9	325	35	336.3
150	15	162.3	230	100	216.3	325	50	333.7
150	25	160.1	230	150	181.5	325	75	327.9
150	40	155.6	230	200	117.5	325	100	320.0
150	50	151.7	230	215	84.4	325	125	309.8
150	75	138.3	250	5	264.2	325	150	297.3
150	100	118.3	250	15	263.3	325	175	281.9
150	120	94.9	250	25	262.0	325	200	263.4
175	5	188.9	250	35	260.2	325	250	213.0
175	15	187.6	250	50	256.9	325	275	177.5
175	25	185.7	250	75	249.3	325	285	160.0
175	35	183.3	250	100	238.8	325	300	128.0
175	50	178.5	250	125	225.0	350	5	364.5
175	75	167.3	250	150	207.4	350	15	363.8
175	100	151.2	250	175	184.7	350	25	362.8
175	150	94.2	250	200	154.9	350	35	361.6
200	5	214.1	250	230	101.0	350	50	359.2
200	15	212.9	275	5	289.3	350	75	353.7
200	25	211.3	275	15	288.4	350	100	346.4
200	35	209.1	275	25	287.2	350	125	337.1
200	50	204.9	275	35	285.7	350	150	325.6
200	75	195.3	275	50	282.6	350	175	311.7
200	100	181.7	275	75	275.7	350	200	295.0

TABLE A (*Continued*)

Intake Lb.	Discharge Lb.	Resultant	Intake Lb.	Discharge Lb.	Resultant	Intake Lb.	Discharge Lb.	Resultant
350	225	275.0	400	75	405.1	425	300	307.2
350	250	251.0	400	100	398.8	425	325	279.3
350	275	221.6	400	125	390.2	425	350	245.7
350	300	184.4	400	150	380.8	425	375	203.7
350	325	132.8	400	175	369.0	425	400	146.2
375	5	389.5	400	200	355.0	450	5	464.6
375	15	388.8	400	225	338.6	450	15	464.0
375	25	387.9	400	250	319.4	450	25	463.3
375	35	386.8	400	275	296.9	450	35	462.3
375	50	384.6	400	300	270.2	450	50	460.4
375	75	379.5	400	325	238.0	450	75	456.2
375	100	372.7	400	350	197.5	450	100	450.5
375	125	364.0	400	375	141.9	450	125	443.4
375	150	353.4	425	5	439.6	450	150	434.7
375	175	340.6	425	15	439.0	450	175	424.4
375	200	325.4	425	25	438.2	450	200	412.3
375	225	307.4	425	35	437.2	450	225	398.3
375	250	286.1	425	50	435.2	450	250	382.1
375	275	260.8	425	75	430.7	450	275	363.5
375	300	230.0	425	100	424.7	450	300	342.1
375	325	191.1	425	125	417.1	450	325	317.2
375	350	137.4	425	150	407.9	450	350	288.1
400	5	414.5	425	175	396.9	450	375	253.2
400	15	413.9	425	200	383.9	450	400	209.8
400	25	413.1	425	225	368.8	450	425	150.4
400	35	412.0	425	250	351.3	475	50	485.7
400	50	409.9	425	275	330.9	500	50	510.0

TABLE B

Length of Line Miles	Multiplier	Length of Line Miles	Multiplier	Length of Line Miles	Multiplier
1/8	2880.	19	231.2	61	129.1
1/4	2016.	20	225.5	62	128.1
3/8	1652.4	21	220.1	63	126.9
1/2	1419.7	22	214.9	64	126.0
5/8	1275.9	23	210.0	65	125.1
3/4	1158.6	24	205.7	66	124.1
7/8	1083.7	25	201.6	67	123.1
1	1008.0	26	197.6	68	122.2
1 1/2	826.2	27	193.8	69	121.3
1 3/4	763.6	28	190.5	70	120.4
2	714.9	29	187.0	72	118.7
2 1/2	638.0	30	183.9	74	117.2
2 3/4	607.2	31	181.0	76	115.6
3	582.7	32	178.0	78	114.2
3 1/2	539.0	33	175.6	80	112.7
4	504.0	34	172.9	82	111.2
4 1/2	475.5	35	170.3	84	109.9
5	450.0	36	168.0	86	108.7
5 1/2	428.9	37	165.8	88	107.5
6	411.4	38	163.6	90	106.2
6 1/2	395.3	39	161.3	92	105.1
7	380.4	40	159.5	94	103.9
7 1/2	367.9	41	157.5	96	102.9
8	356.2	42	155.6	98	101.8
8 1/2	345.2	43	153.7	100	100.8
9	336.0	44	152.0	102	99.8
9 1/2	327.3	45	150.2	105	98.3
10	319.0	46	148.7	107	97.5
10 1/2	311.1	47	146.9	110	96.0
11	303.6	48	145.4	112	95.3
11 1/2	297.3	49	144.0	115	93.9
12	291.3	50	142.6	118	92.8
12 1/2	284.7	51	141.2	120	92.0
13	276.4	52	139.8	122	91.2
13 1/2	274.6	53	138.5	125	90.2
14	269.5	54	137.1	130	88.4
14 1/2	264.6	55	135.8	135	86.8
15	260.5	56	134.8	140	85.2
15 1/2	255.8	57	133.5	145	83.7
16	252.0	58	132.3	150	82.3
17	244.7	59	131.2		
18	237.5	60	130.1		

TABLE C

MULTIPLIERS FOR DIAMETERS OTHER THAN ONE INCH

Size of Pipe Inches	Multiplier	Size of Pipe Inches	Multiplier	Size of Pipe Inches	Multiplier
¼	.0317	3	16.50	12	556
½	.1810	4	34.10	16	1160
¾	.5012	5	60.00	18	1570
1	1.0000	5⅝	81.00	20	2055
1½	2.9300	6	95.00	24	3285
2	5.9200	8	198.00	30	5830
2½	10.3700	10	350.00	36	9330

by adding the figures opposite 15 and 25 and dividing by 2, which, computed as above, gives a discharge of 9,469,154 cubic feet.

The measure for wrought iron pipes greater than 12 inches in diameter is taken from the outside. For pipes of ordinary thickness the corresponding inside diameters and multipliers are as follows:

Outside Diameter	Inside Diameter	Multiplier
15	14¼	863
16	15¼	1025
18	17¼	1410
20	19¼	1860

The preceding tables can also be used to determine the pressures or the size of pipe necessary to convey a certain quantity of gas.

Example—Required the pressure to furnish say, 9,500,000 cubic feet, per 24 hours, through 8-inch pipe 20 miles long.

$\frac{9{,}500{,}000}{198} = 48{,}030$ that one-inch pipe must convey, per

24 hours; opposite 20 miles (Table B) the number is 225.5, which governs the capacity for this particular length

$$\frac{48{,}030}{225.5} = 212.9,$$ which number must be compared to a combination of high and low pressures in Table A. Upon inspection of this table it will be found that 200 pounds intake and 15 pounds outlet will fulfill the condition. Table A also shows a number of other combinations which are equal to 212.9, or close to it, any of which will apply equally well. If the size of the line is taken at 10 inches in diameter, then

$$\frac{9{,}500{,}000}{350} = 27{,}143$$ is the amount which one-inch pipe must convey and $\frac{27{,}143}{225.5} = 120$. By inspecting Table A, 110 intake and 20 pounds discharge will be the pressures required.

If it is required to find the size of pipe necessary to convey 9,500,000 cubic feet in 24 hours, and the other conditions remain the same, then $198 \times 212.9 \times 225.5 = 9{,}500{,}000$; therefore $9{,}500{,}000 \div (212.9 \times 225.5) = 198$, and this number is found opposite 8-inch pipe in Table C. Say that 4,550,000 cubic feet are required when the other conditions remain, then $4{,}550{,}000 \div (212.9 \times 225.5) = 95 +$. By referring to Table C it is found that 95 is opposite the size of 6-inch, which is therefore the required size. The numbers found in Tables A and B corresponding with the pressures and lengths, multiplied together and divided into the quantity, must give the number corresponding to the size of pipe. Any of these quantities in the formula can be determined by multiplying the two known factors and dividing their product into the known cubic feet.

Examples Showing Application of Table D—Suppose that a line is composed of 10-inch and 16-inch pipe, that there are 30 miles of the former and 20 miles of the latter,

TABLE D

COMPARATIVE CAPACITY OF PIPES OF DIFFERENT GAS APPLIED TO LINES IN WHICH A

Size of Pipe Ins.	1	2	3	4	5	6	8
	Comparative *Note*—In making computations observe						
1	1	34	265	1,150	3,573	9,035	39,000
2	.0294	1	7.8	34	105	266	1,150
3	.0037	.128	1	4.34	13.45	34	147
4	....	.0295	.231	1	3.11	7.80	34
5	....	....	.0741	.3274	1	2.51	10.94
6	....	....	.0293	.1272	.3954	1	4.34
8	....	....	.0037	.0295	.0915	.2316	1
10	....	....	....	.0094	.0295	.0741	.3260
12	....	....	....	....	.0116	.0295	.1272
15¼	....	....	....	....	....	.0086	.0373
16	....	....	....	....	....	....	.0295
17¼	....	....	....	....	....	....	....
18	....	....	....	....	....	....	....
19¼	....	....	....	....	....	....	....
20	....	....	....	....	....	....	....

The above table is based upon the fact that the length of pipes for the same quantity of gas varies as the 5.0835 power of their diameters. The value of the increasing or decreasing sizes can readily be appreciated by an inspection of the table.

It is particularly useful in securing the value of a series of different sizes of pipes in the same line by reducing the values of the several sizes to some one of the sizes in use. For example, on the horizontal line in the table a unit, say 1 foot or 1 mile of 8-inch pipe, has

TABLE D

DIAMETERS CONVEYING THE SAME QUANTITY OF NUMBER OF DIFFERENT SIZES ARE USED

(By F. H. Oliphant)

10	12	15¼	16	17¼	18	19¼	20

VALUES
carefully the decimal notations.

121,210	306,380	1,043,700	1,326,000	1,937,700	2,406,100	3,382,300	4,120,000
3,570	9,035	30,700	39,000	57,000	70,765	99,480	121,178
457	1,150	3,940	5,004	7,312	9,040	12,760	15,550
105	265	908	1,150	1,685	2,092	2,940	3,575
34	85.75	292	371	542.3	673.4	946.6	1,150
13.45	34	115.5	147	215	265	375	457
3.11	7.80	26.75	34	50	61.70	86.70	105
1	2.52	8.61	10.94	16	19.85	27.90	34
.3954	1	3.41	4.34	6.32	7.80	11.00	13.45
.1161	.2935	1	1.27	1.85	2.30	3.24	3.95
.0915	.2316	.7871	1	1.46	1.81	2.55	3.11
.0630	.1582	.5386	.6843	1	1.24	1.75	2.13
....	.1273	.4337	.5510	.8053	1	1.41	1.71
....	....	.3085	.3920	.5728	.7113	1	1.22
....	....	....	.3218	.4703	.5840	.8209	1

the same value as 3.11 feet or miles of 10-inch, 7.80 feet or miles of 12-inch and 105 feet or miles of 20-inch.

When smaller sizes are used 1 foot or 1 mile of 8-inch pipe is equivalent to 0.2316 feet or mile of 6-inch pipe, etc.

Larger diameters, when compared to smaller, give the equivalent in an increased length, and smaller diameters give a less length when compared with a diameter assumed to be 1.

and that the pressure is 200 pounds at the end of the 10-inch section, next the source, and 25 pounds at the discharge end of the 16-inch section. After adding 15 pounds to each of the pressures to obtain the actual pressure, these become 215 and 40 pounds, respectively.

The formula is

$$Q = 42a\sqrt{\frac{P_1^2 - P_2^2}{l}}$$

$$\sqrt{P_1^2 - P_2^2} = \sqrt{215^2 - 40^2} = \sqrt{44{,}625} = 211.3$$

For 10-inch pipe the multiplier is $a = 350$, as given in Table C. The length of equivalent 10-inch pipe is now to be determined, so that it can be substituted in the formula. One mile of 16-inch pipe is equivalent to 0.0915 mile of 10-inch, and 20 miles of 16-inch will therefore be equivalent to $30 + 1.83 = 31.83$ miles of 10-inch pipe. The same result can be obtained another way, as follows: 1 mile of 10-inch pipe is equivalent to 10.94 miles of 16-inch. Hence 20 miles of 16-inch will be equivalent to $\frac{20.00}{10.94} = 1.83$ miles of 10-inch pipe.

The equivalent lengths thus determined remain the same for all variations of pressure at the intake and outlet.

By substituting the determined quantities, the equation

$$Q = 42 \times 350\sqrt{\frac{44625}{31.83}}. \quad Q = 42 \times \frac{350 \times 211.3}{5.63} = 551{,}700$$

cubic feet per hour.

Suppose the pressure be increased to 400 pounds at the intake and 25 pounds at the outlet; then

$$\sqrt{415^2 - 40^2} = \sqrt{170{,}625} = 413.$$

As compared with 211.3 this quantity would be 1.95 times 211.3, showing the increase in quantity to be almost directly as the intake pressure when the outlet pressure is small by comparison with the intake.

The proof of this illustration can be shown by substituting the equivalent distance for the 16-inch pipe and the multiplier for the same instead of the 10-inch.

By referring to the table it will be found that 1 mile of 10-inch pipe is equivalent to 10.94 miles of 16-inch. Thirty miles of 10-inch are therefore equivalent to $30 \times 10.94 = 328$ miles of 16-inch. The whole line is consequently equivalent to $328 + 20 = 348$ miles of 16-inch pipe.

In the table of multipliers for diameters greater than one inch, opposite 16 we find 1160; then if the pressures remain 200 and 25 pounds respectively, as before,

$$Q = 42\sqrt{\frac{44625}{348}} \times 1160,\ Q = \frac{42 \times 211.3 \times 1160}{18.66} = 551{,}690$$

cubic feet per hour, which is almost exactly the same quantity as obtained before.

For any specific gravity other than 0.6, multiply the final result by

$$\sqrt{\frac{0.6}{\text{sp. gr. gas}}}$$

For temperatures of flowing gas when observed above 60 deg. fahr., deduct 1 per cent. for each 10 degrees, and add a like amount for temperatures less than 60 deg. fahr.

Reduction in Pressure of Natural Gas in Pipes, Owing to Fittings—The drop in pressure due to friction in ells, tees and globe valves of ordinary manufacture is allowed by an addition to the length of straight pipe.

The following table shows the additional length required to compensate for friction due to ells, and tees. For globe valves increase the values shown in the table by 50 per cent.

Diameter of Pipe Inches	Additional Length, Feet	Diameter of Pipe Inches	Additional Length, Feet
1	1.5	6	27
1¼	2.0	7	29⅓
1½	2⅔	8	35⅓
2	4⅔	10	46⅔
2½	6⅔	12	58⅔
3	8⅔	15	76⅔
3½	10⅔	18	95
4	13½	20	108
5	18⅔	24	133

Table of Multipliers for Different Specific Gravities—The following correction factors apply to all computations of the Pitot tube and orifice measurements and of the flow of gas in pipes, when the formulae used are based on a standard specific gravity of gas of 0.60. In practice, the corrections for gravity are usually neglected unless accurate results are required.

TABLE OF MULTIPLIERS FOR DIFFERENT SPECIFIC GRAVITIES

Specific Gravity	Multiplier	Specific Gravity	Multiplier
.75	.894	.6	1.000
.70	.925	.55	1.044
.65	.960	.50	1.095

Pipe Capacity—The capacities of pipe lines of different sizes vary as

$$\sqrt{d^{5.0835}} = d^{2.542}$$

where d is the diameter. The area of a pipe varies as the square of the diameter, or as d^2.

Tables for Computing the Flow of Natural Gas in Pipe Lines—Based upon formula by F. H. Oliphant in "Production of Natural Gas in 1900," United States Geological Survey.

$$\text{Formula} — Q = 42a.\sqrt{\frac{P_1^2 - P_2^2}{L}}$$

Q = cubic feet per hour.
42 = constant.
a = computed value for diameters.
P_1 = gauge pressure + 15 pounds at intake end of line.
P_2 = gauge pressure + 15 pounds at discharge end of line.
L = length of line in miles.

For value of A, see Table of Multipliers.

Calculated for 1-inch pipe (flow in thousands of cubic feet) for 24 hours at normal pressure of 14.4 pounds.

Specific gravity of gas taken at 0.6. For any other specific gravity multiply final result by $\sqrt{\frac{0.6}{\text{sp.gr.gas}}}$

For other diameters, or value A, use the following multipliers:

¼ inch	.0317	2¼ inches	10.37	8 inches	198.0
½ inch	.1810	3 inches	16.50	10 inches	350.0
¾ inch	.5012	4 inches	34.10	12 inches	556.0
1 inch	1.0000	5 inches	60.00	16 inches	1160.0
1½ inches	2.9300	5⅝ inches	81.00	18 inches	1570.0
2 inches	5.9200	6 inches	95.00		

For pipes greater than 12 inches in diameter the measure is taken from the outside and for pipes of ordinary thickness the corresponding inside diameters and multipliers are as follows:

Outside	Inside	Multiplier
15 inch	14¼ inch	863
16 inch	15¼ inch	1025
18 inch	17¼ inch	1410
20 inch	19¼ inch	1860

For riveted or cast pipe with inside diameters as below, use multipliers opposite:

20 inch	2055	30 inch	5830
24 inch	3285	36 inch	9330

All pipe line capacity tables on pages 236 to 324 are based on the foregoing formula.

CAPACITY, IN CUBIC FEET, OF 1″ PIPE LINE 1 MILE LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	15,000												
20	28,000	24,000	18,000										
30	40,000	37,000	33,000	28,000	20,000								
40	51,000	49,000	46,000	42,000	38,000	31,000							
50	62,000	60,000	58,000	55,000	51,000	47,000	34,000						
60	72,000	71,000	69,000	66,000	63,000	60,000	51,000	37,000					
70	83,000			78,000		72,000	65,000	55,000					
80	93,000			89,000		84,000	78,000	69,000					
90	103,000			99,000		95,000	90,000	83,000	54,000				
100	114,000			110,000	108,000	106,000	100,000	95,000	72,000				
125	139,000				135,000		129,000	124,000	108,000	80,000			
150	165,000				161,000		156,000	152,000	139,000	119,000	107,000		
175	190,000				187,000			179,000	168,000	152,000	129,000	94,000	
200	215,000				212,000			206,000	196,000	183,000	164,000	139,000	
225	241,000				237,000			232,000		211,000	196,000	175,000	106,000
250	266,000				264,000			258,000		240,000	226,000	209,000	156,000
275	291,000				289,000			284,000		268,000		240,000	196,000
300	316,000				315,000			310,000		295,000		270,000	232,000
325	342,000				340,000			336,000		322,000		299,000	265,000
350	367,000				365,000			362,000		349,000		328,000	297,000
375	392,000				391,000			387,000		375,000		356,000	328,000
400	417,000				416,000			412,000		410,000		383,000	357,000

CAPACITY, IN CUBIC FEET, OF 2″ PIPE LINE 1 MILE LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	89,000	....	....	....	....	....	....	....	....	....	....	....	....
20	167,000	146,000	107,000	....	....	....	....	....	....	....	....	....	....
30	241,000	223,000	199,000	168,000	119,000	....	....	....	....	....	....	....	....
40	305,000	292,000	275,000	253,000	225,000	188,000	....	....	....	....	....	....	....
50	368,000	358,000	344,000	326,000	305,000	279,000	206,000	....	....	....	....	....	....
60	431,000	421,000	410,000	395,000	....	358,000	304,000	223,000	....	....	....	....	....
70	492,000	....	....	462,000	....	430,000	386,000	326,000	....	....	....	....	....
80	553,000	....	....	526,000	....	499,000	462,000	412,000	....	....	....	....	....
90	615,000	....	....	590,000	....	566,000	533,000	492,000	322,000	....	....	....	....
100	676,000	....	....	653,000	....	629,000	596,000	566,000	427,000	....	....	....	....
125	827,000	....	....	....	800,000	....	767,000	739,000	639,000	476,000	....	....	....
150	977,000	....	....	....	955,000	....	928,000	905,000	825,000	705,000	638,000	....	....
175	1,127,000	....	....	....	1,108,000	....	....	1,065,000	998,000	901,000	766,000	562,000	....
200	1,277,000	....	....	....	1,260,000	....	....	1,222,000	1,165,000	1,084,000	973,000	822,000	....
225	1,426,000	....	....	....	1,408,000	....	....	1,378,000	....	1,253,000	1,162,000	1,038,000	632,000
250	1,576,000	....	....	....	1,563,000	....	....	1,532,000	....	1,424,000	1,342,000	1,237,000	924,000
275	1,726,000	....	....	....	1,713,000	....	....	1,686,000	....	1,588,000	....	1,423,000	1,161,000
300	1,876,000	....	....	....	1,864,000	....	....	1,839,000	....	1,750,000	....	1,600,000	1,373,000
325	2,025,000	....	....	....	2,014,000	....	....	1,991,000	....	1,909,000	....	1,773,000	1,571,000
350	2,174,000	....	....	....	2,164,000	....	....	2,143,000	....	2,066,000	....	1,942,000	1,760,000
375	2,324,000	....	....	....	2,314,000	....	....	2,294,000	....	2,223,000	....	2,108,000	1,941,000
400	2,473,000	....	....	....	2,464,000	....	....	2,440,000	....	2,379,000	....	2,272,000	2,118,000

CAPACITY, IN CUBIC FEET, OF 2″ PIPE LINE 2 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	63,000	...	...	...	...	...	...	...	...	...	...	...	...
20	118,000	103,000	76,000	...	...	...	...	...	...	...	...	...	...
30	171,000	158,000	141,000	119,000	...	...	...	...	...	...	...	...	...
40	216,000	207,000	195,000	159,000	133,000	96,000	...	...	...	...	...	...	...
50	261,000	253,000	244,000	231,000	216,000	198,000	146,000	...	...	...	...	...	...
60	305,000	299,000	291,000	280,000	268,000	253,000	215,000	158,000	...	...	...	...	...
70	349,000	...	...	327,000	...	305,000	274,000	231,000	...	...	...	...	...
80	392,000	...	...	373,000	...	354,000	327,000	292,000	...	...	...	...	...
90	436,000	...	...	418,000	...	401,000	378,000	349,000	228,000	...	...	...	...
100	479,000	...	...	463,000	456,000	446,000	423,000	401,000	303,000	...	...	...	...
125	586,000	...	...	...	567,000	...	544,000	524,000	453,000	333,000	...	...	...
150	693,000	...	...	...	677,000	...	658,000	642,000	585,000	500,000	452,000	...	...
175	799,000	...	...	...	785,000	...	...	755,000	708,000	639,000	543,000	398,000	...
200	906,000	...	...	...	894,000	...	...	867,000	826,000	768,000	690,000	583,000	...
225	1,011,000	...	...	...	998,000	...	...	977,000	...	888,000	...	736,000	448,000
250	1,118,000	...	...	...	1,110,000	...	...	1,087,000	...	1,010,000	...	877,000	655,000
275	1,224,000	...	...	...	1,215,000	...	...	1,196,000	...	1,126,000	...	1,009,000	823,000
300	1,330,000	...	...	...	1,322,000	...	...	1,304,000	...	1,241,000	...	1,135,000	974,000
325	1,436,000	...	...	...	1,428,000	...	...	1,412,000	...	1,354,000	...	1,258,000	1,114,000
350	1,542,000	...	...	...	1,535,000	...	...	1,520,000	...	1,466,000	...	1,378,000	1,248,000
375	1,648,000	...	...	...	1,641,000	...	...	1,627,000	...	1,577,000	...	1,495,000	1,377,000
400	1,754,000	...	...	...	1,748,000	...	...	1,730,000	...	1,687,000	...	1,611,000	1,502,000

CAPACITY, IN CUBIC FEET, OF 2″ PIPE LINE 3 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	51,000												
20	96,000	84,000	62,000										
30	139,000	128,000	115,000	97,000	68,000								
40	176,000	169,000	158,000	146,000	130,000	108,000							
50	213,000	206,000	199,000	189,000	176,000	161,000	119,000						
60	249,000	243,000	237,000	228,000		206,000	175,000	128,000					
70	284,000			267,000		248,000	223,000	188,000					
80	320,000			304,000		288,000	267,000	238,000					
90	355,000			341,000		327,000	308,000	284,000	186,000				
100	390,000			377,000		363,000	344,000	327,000	246,000				
125	478,000				462,000		443,000	427,000	369,000	275,000			
150	564,000				552,000		536,000	523,000	476,000	408,000	369,000		
175	651,000				640,000			615,000	577,000	520,000	442,000	324,000	
200	738,000				728,000			706,000	673,000	626,000	562,000	475,000	
225	824,000				813,000			796,000		724,000	672,000	600,000	365,000
250	911,000				903,000			886,000		823,000	776,000	715,000	534,000
275	997,000				990,000			974,000		918,000		822,000	671,000
300	1,084,000				1,077,000			1,062,000		1,011,000		925,000	793,000
325	1,170,000				1,164,000			1,150,000		1,103,000		1,025,000	908,000
350	1,257,000				1,251,000			1,238,000		1,194,000		1,122,000	1,017,000
375	1,343,000				1,337,000			1,326,000		1,285,000		1,218,000	1,122,000
400	1,429,000				1,424,000			1,410,000		1,375,000		1,313,000	1,224,000

CAPACITY, IN CUBIC FEET, OF 2″ PIPE LINE 4 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	44,000	...	...	...	...	...	...	...	...	...	...	...	...
20	83,000	73,000	53,000	...	...	...	...	...	...	...	...	...	...
30	120,000	111,000	99,000	84,000	59,000	...	...	...	...	...	...	...	...
40	152,000	146,000	137,000	126,000	112,000	94,000	...	...	...	...	...	...	...
50	184,000	178,000	172,000	163,000	152,000	139,000	103,000	...	...	...	...	...	...
60	215,000	210,000	205,000	197,000	...	178,000	152,000	111,000	...	...	...	...	...
70	246,000	...	...	231,000	...	215,000	193,000	163,000	...	...	...	...	...
80	276,000	...	...	263,000	...	249,000	231,000	206,000	...	...	...	...	...
90	307,000	...	...	295,000	...	283,000	266,000	246,000	161,000	...	...	...	...
100	337,000	...	...	326,000	...	314,000	298,000	283,000	213,000	...	...	...	...
125	413,000	...	...	...	400,000	...	383,000	369,000	319,000	238,000	...	...	...
150	488,000	...	...	...	477,000	...	464,000	452,000	412,000	352,000	319,000	...	...
175	563,000	...	...	...	553,000	...	...	532,000	499,000	450,000	383,000	280,000	...
200	638,000	...	...	...	630,000	...	...	611,000	582,000	542,000	486,000	411,000	...
225	713,000	...	...	...	703,000	...	...	689,000	...	626,000	581,000	519,000	316,000
250	788,000	...	...	...	781,000	...	...	766,000	...	712,000	671,000	618,000	462,000
275	862,000	...	...	...	856,000	...	...	842,000	...	794,000	...	711,000	580,000
300	937,000	...	...	...	932,000	...	...	919,000	...	874,000	...	800,000	686,000
325	1,012,000	...	...	...	1,007,000	...	...	995,000	...	954,000	...	886,000	785,000
350	1,087,000	...	...	...	1,082,000	...	...	1,071,000	...	1,033,000	...	971,000	879,000
375	1,161,000	...	...	...	1,157,000	...	...	1,147,000	...	1,111,000	...	1,054,000	970,000
400	1,236,000	...	...	...	1,232,000	...	...	1,222,000	...	1,189,000	...	1,135,000	1,058,000

CAPACITY, IN CUBIC FEET, OF 2″ PIPE LINE 5 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	39,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	74,000	65,000	47,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	107,000	99,000	89,000	75,000	53,000	.....	.....	.....	.....	.....	.....	.....	.....
40	136,000	130,000	122,000	112,000	100,000	84,000	.....	.....	.....	.....	.....	.....	.....
50	164,000	159,000	153,000	145,000	136,000	124,000	92,000	.....	.....	.....	.....	.....	.....
60	192,000	188,000	183,000	176,000	168,000	159,000	135,000	99,000	.....	.....	.....	.....	.....
70	220,000	.....	.....	206,000	.....	192,000	172,000	145,000	.....	.....	.....	.....	.....
80	247,000	.....	.....	235,000	.....	222,000	206,000	184,000	.....	.....	.....	.....	.....
90	274,000	.....	.....	263,000	.....	252,000	238,000	219,000	143,000	.....	.....	.....	.....
100	301,000	.....	.....	291,000	287,000	281,000	266,000	252,000	190,000	.....	.....	.....	.....
125	369,000	.....	.....	.....	357,000	.....	342,000	330,000	285,000	212,000	.....	.....	.....
150	436,000	.....	.....	.....	426,000	.....	414,000	404,000	368,000	315,000	285,000	.....	.....
175	503,000	.....	.....	.....	494,000	.....	.....	475,000	445,000	402,000	342,000	250,000	.....
200	570,000	.....	.....	.....	562,000	.....	.....	545,000	520,000	484,000	434,000	367,000	.....
225	636,000	.....	.....	.....	628,000	.....	.....	615,000	.....	559,000	519,000	463,000	282,000
250	703,000	.....	.....	.....	697,000	.....	.....	684,000	.....	636,000	.....	552,000	412,000
275	770,000	.....	.....	.....	765,000	.....	.....	752,000	.....	709,000	.....	635,000	518,000
300	837,000	.....	.....	.....	832,000	.....	.....	821,000	.....	781,000	.....	714,000	613,000
325	901,000	.....	.....	.....	899,000	.....	.....	888,000	.....	852,000	.....	792,000	701,000
350	971,000	.....	.....	.....	966,000	.....	.....	956,000	.....	922,000	.....	867,000	785,000
375	1,037,000	.....	.....	.....	1,033,000	.....	.....	1,024,000	.....	992,000	.....	941,000	866,000
400	1,104,000	.....	.....	.....	1,100,000	.....	.....	1,089,000	.....	1,062,000	.....	1,014,000	945,000

CAPACITY, IN CUBIC FEET, OF 2″ PIPE LINE 7 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	33,000	....	....	....	....	....	....	....	....	....	....	....	....
20	63,000	55,000	40,000	....	....	....	....	....	....	....	....	....	....
30	91,000	84,000	75,000	63,000	45,000	....	....	....	....	....	....	....	....
40	115,000	110,000	103,000	95,000	85,000	71,000	....	....	....	....	....	....	....
50	139,000	135,000	129,000	123,000	115,000	105,000	77,000	....	....	....	....	....	....
60	162,000	159,000	154,000	149,000	....	135,000	114,000	84,000	....	....	....	....	....
70	185,000	....	....	174,000	....	162,000	145,000	123,000	....	....	....	....	....
80	208,000	....	....	198,000	....	188,000	174,000	155,000	....	....	....	....	....
90	232,000	....	....	222,000	....	213,000	201,000	185,000	121,000	....	....	....	....
100	255,000	....	....	246,000	....	237,000	225,000	213,000	161,000	....	....	....	....
125	311,000	....	....	....	302,000	....	289,000	279,000	241,000	179,000	....	....	....
150	368,000	....	....	....	360,000	....	350,000	341,000	311,000	266,000	240,000	....	....
175	425,000	....	....	....	418,000	....	....	401,000	376,000	339,000	289,000	212,000	....
200	481,000	....	....	....	475,000	....	....	461,000	439,000	409,000	367,000	310,000	....
225	538,000	....	....	....	531,000	....	....	519,000	....	472,000	438,000	391,000	238,000
250	594,000	....	....	....	589,000	....	....	578,000	....	537,000	506,000	466,000	348,000
275	651,000	....	....	....	646,000	....	....	636,000	....	599,000	....	536,000	438,000
300	707,000	....	....	....	703,000	....	....	693,000	....	660,000	....	603,000	518,000
325	763,000	....	....	....	759,000	....	....	751,000	....	720,000	....	669,000	592,000
350	820,000	....	....	....	816,000	....	....	808,000	....	779,000	....	732,000	664,000
375	876,000	....	....	....	873,000	....	....	865,000	....	838,000	....	795,000	732,000
400	933,000	....	....	....	929,000	....	....	920,000	....	897,000	....	857,000	799,000

CAPACITY, IN CUBIC FEET, OF 2″ PIPE LINE 10 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	28,000	...	...	...	...	...	...	...	...	...	...	...	...
20	52,000	46,000	33,000	...	...	...	...	...	...	...	...	...	...
30	76,000	70,000	63,000	53,000	37,000	...	...	...	...	...	...	...	...
40	96,000	92,000	87,000	80,000	71,000	59,000	...	...	...	...	...	...	...
50	116,000	113,000	108,000	103,000	96,000	85,000	65,000	...	...	...	...	...	...
60	136,000	133,000	129,000	125,000	119,000	113,000	96,000	70,000	...	...	...	...	...
70	155,000	...	...	146,000	...	136,000	122,000	103,000	...	...	...	...	...
80	175,000	...	...	166,000	...	158,000	146,000	130,000	...	...	...	...	...
90	194,000	...	...	186,000	...	179,000	168,000	155,000	101,000	...	...	...	...
100	213,000	...	...	206,000	203,000	199,000	188,000	179,000	135,000	...	...	...	...
125	261,000	...	...	...	253,000	...	242,000	231,000	202,000	150,000	...	...	...
150	309,000	...	...	...	302,000	...	293,000	286,000	261,000	223,000	202,000	...	...
175	356,000	...	...	...	350,000	...	...	337,000	315,000	285,000	242,000	177,000	...
200	404,000	...	...	...	399,000	...	...	386,000	368,000	343,000	308,000	260,000	...
225	451,000	...	...	...	445,000	...	...	436,000	...	396,000	367,000	328,000	200,000
250	498,000	...	...	...	494,000	...	...	485,000	...	450,000	...	391,000	292,000
275	546,000	...	...	...	542,000	...	...	533,000	...	502,000	...	450,000	367,000
300	593,000	...	...	...	590,000	...	...	582,000	...	553,000	...	506,000	434,000
325	640,000	...	...	...	637,000	...	...	630,000	...	601,000	...	561,000	497,000
350	688,000	...	...	...	685,000	...	...	678,000	...	651,000	...	614,000	557,000
375	735,000	...	...	...	732,000	...	...	726,000	...	703,000	...	667,000	614,000
400	782,000	...	...	...	780,000	...	...	772,000	...	753,000	...	719,000	670,000

CAPACITY, IN CUBIC FEET, OF 2″ PIPE LINE 15 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	23,000	...	...	...	...	...	...	...	...	...	...	...	...
20	43,000	37,000	27,000	...	...	...	...	...	...	...	...	...	...
30	62,000	57,000	51,000	43,000	30,000	...	...	...	...	...	...	...	...
40	78,000	75,000	71,000	65,000	58,000	48,000	...	...	...	...	...	...	...
50	95,000	92,000	88,000	84,000	78,000	72,000	53,000	...	...	...	...	...	...
60	111,000	109,000	106,000	102,000	97,000	92,000	78,000	57,000	...	...	...	...	...
70	127,000	...	...	119,000	...	111,000	99,000	84,000	...	...	...	...	...
80	143,000	...	...	136,000	...	129,000	119,000	106,000	...	...	...	...	...
90	158,000	...	...	152,000	...	146,000	137,000	127,000	83,000	...	...	...	...
100	174,000	...	...	168,000	...	162,000	154,000	146,000	110,000	...	...	...	...
125	213,000	...	...	...	206,000	...	198,000	191,000	165,000	123,000	...	...	...
150	252,000	...	...	...	246,000	...	239,000	233,000	213,000	182,000	165,000	...	...
175	291,000	...	...	...	286,000	...	...	275,000	257,000	232,000	197,000	145,000	...
200	330,000	...	...	...	325,000	...	...	315,000	301,000	280,000	251,000	212,000	...
225	368,000	...	...	...	363,000	...	...	356,000	...	323,000	300,000	268,000	163,000
250	407,000	...	...	...	404,000	...	...	396,000	...	368,000	...	319,000	238,000
275	446,000	...	...	...	442,000	...	...	435,000	...	410,000	...	367,000	300,000
300	484,000	...	...	...	481,000	...	...	475,000	...	452,000	...	413,000	354,000
325	523,000	...	...	...	520,000	...	...	514,000	...	493,000	...	458,000	406,000
350	562,000	...	...	...	559,000	...	...	553,000	...	534,000	...	502,000	454,000
375	600,000	...	...	...	598,000	...	...	593,000	...	574,000	...	544,000	501,000
400	639,000	...	...	...	637,000	...	...	630,000	...	614,000	...	587,000	547,000

CAPACITY, IN CUBIC FEET, OF 3″ PIPE LINE 1 MILE LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	249,000	....	....	....	....	....	....	....	....	....	....	....	....
20	465,000	407,000	299,000	....	....	....	....	....	....	....	....	....	....
30	673,000	622,000	557,000	470,000	332,000	....	....	....	....	....	....	....	....
40	851,000	814,000	766,000	705,000	628,000	525,000	....	....	....	....	....	....	....
50	1,027,000	997,000	959,000	911,000	851,000	780,000	575,000	....	....	....	....	....	....
60	1,202,000	1,175,000	1,144,000	1,102,000	....	997,000	848,000	622,000	....	....	....	....	....
70	1,373,000	....	....	1,288,000	....	1,199,000	1,077,000	909,000	....	....	....	....	....
80	1,543,000	....	....	1,468,000	....	1,392,000	1,288,000	1,150,000	....	....	....	....	....
90	1,714,000	....	....	1,646,000	....	1,578,000	1,486,000	1,372,000	898,000	....	....	....	....
100	1,884,000	....	....	1,821,000	....	1,754,000	1,663,000	1,578,000	1,190,000	....	....	....	....
125	2,305,000	....	....	....	2,232,000	....	2,140,000	2,062,000	1,782,000	1,327,000	....	....	....
150	2,724,000	....	....	....	2,662,000	....	2,587,000	2,523,000	2,300,000	1,967,000	1,779,000	....	....
175	3,141,000	....	....	....	3,088,000	....	....	2,968,000	2,782,000	2,511,000	2,135,000	1,566,000	....
200	3,560,000	....	....	....	3,514,000	....	....	3,407,000	3,248,000	3,022,000	2,711,000	2,293,000	....
225	3,976,000	....	....	....	3,925,000	....	....	3,841,000	....	3,492,000	3,241,000	2,893,000	1,762,000
250	4,394,000	....	....	....	4,357,000	....	....	4,272,000	....	3,971,000	3,742,000	3,419,000	2,576,000
275	4,811,000	....	....	....	4,776,000	....	....	4,700,000	....	4,427,000	....	3,966,000	3,236,000
300	5,229,000	....	....	....	5,197,000	....	....	5,125,000	....	4,878,000	....	4,462,000	3,828,000
325	5,644,000	....	....	....	5,614,000	....	....	5,550,000	....	5,322,000	....	4,944,000	4,380,000
350	6,062,000	....	....	....	6,031,000	....	....	5,974,000	....	5,761,000	....	5,415,000	4,906,000
375	6,478,000	....	....	....	6,451,000	....	....	6,396,000	....	6,198,000	....	5,877,000	5,412,000
400	6,893,000	....	....	....	6,870,000	....	....	6,802,000	....	6,632,000	....	6,333,000	5,904,000

CAPACITY, IN CUBIC FEET, OF 3″ PIPE LINE 2 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	176,000	....	....	....	....	....	....	....	....	....	....	....	....
20	330,000	288,000	212,000	....	....	....	....	....	....	....	....	....	....
30	477,000	441,000	395,000	333,000	235,000	....	....	....	....	....	....	....	....
40	603,000	577,000	543,000	500,000	445,000	372,000	....	....	....	....	....	....	....
50	728,000	707,000	680,000	646,000	603,000	553,000	408,000	....	....	....	....	....	....
60	852,000	833,000	811,000	782,000	....	707,000	601,000	441,000	....	....	....	....	....
70	974,000	....	....	914,000	....	850,000	764,000	645,000	....	....	....	....	....
80	1,094,000	....	....	1,041,000	....	987,000	914,000	816,000	....	....	....	....	....
90	1,216,000	....	....	1,167,000	....	1,119,000	1,054,000	973,000	636,000	....	....	....	....
100	1,336,000	....	....	1,291,000	....	1,244,000	1,179,000	1,119,000	844,000	....	....	....	....
125	1,634,000	....	....	....	1,582,000	....	1,518,000	1,462,000	1,264,000	941,000	....	....	....
150	1,932,000	....	....	....	1,888,000	....	1,835,000	1,789,000	1,631,000	1,395,000	1,262,000	....	....
175	2,228,000	....	....	....	2,190,000	....	....	2,105,000	1,973,000	1,781,000	1,514,000	1,111,000	....
200	2,525,000	....	....	....	2,492,000	....	....	2,416,000	2,303,000	2,143,000	1,924,000	1,626,000	....
225	2,820,000	....	....	....	2,783,000	....	....	2,724,000	....	2,476,000	2,298,000	2,052,000	1,250,000
250	3,116,000	....	....	....	3,090,000	....	....	3,030,000	....	2,816,000	2,653,000	2,446,000	1,827,000
275	3,412,000	....	....	....	3,387,000	....	....	3,333,000	....	3,139,000	....	2,813,000	2,295,000
300	3,708,000	....	....	....	3,685,000	....	....	3,635,000	....	3,459,000	....	3,164,000	2,715,000
325	4,003,000	....	....	....	3,981,000	....	....	3,935,000	....	3,774,000	....	3,506,000	3,106,000
350	4,299,000	....	....	....	4,279,000	....	....	4,236,000	....	4,085,000	....	3,840,000	3,479,000
375	4,594,000	....	....	....	4,575,000	....	....	4,536,000	....	4,395,000	....	4,168,000	3,838,000
400	4,889,000	....	....	....	4,872,000	....	....	4,824,000	....	4,703,000	....	4,491,000	4,187,000

CAPACITY, IN CUBIC FEET, OF 3″ PIPE LINE 3 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	144,000												
20	269,000	235,000	173,000										
30	389,000	359,000	322,000	272,000	192,000								
40	492,000	471,000	443,000	407,000	363,000	303,000							
50	594,000	576,000	554,000	526,000	492,000	450,000	332,000						
60	695,000	679,000	661,000	637,000		576,000	490,000	359,000					
70	794,000			745,000		693,000	622,000	525,000					
80	892,000			848,000		804,000	745,000	665,000					
90	991,000			951,000		912,000	859,000	793,000	519,000				
100	1,089,000			1,052,000		1,014,000	961,000	912,000	688,000				
125	1,332,000				1,290,000		1,237,000	1,192,000	1,030,000	767,000			
150	1,574,000				1,539,000		1,495,000	1,458,000	1,329,000	1,137,000	1,028,000		
175	1,816,000				1,785,000			1,716,000	1,608,000	1,451,000	1,234,000	905,000	
200	2,058,000				2,031,000			1,969,000	1,877,000	1,746,000	1,569,000	1,325,000	
225	2,298,000				2,268,000			2,220,000		2,018,000	1,873,000	1,672,000	1,019,000
250	2,540,000				2,518,000			2,469,000		2,295,000	2,163,000	1,993,000	1,489,000
275	2,781,000				2,761,000			2,716,000		2,559,000		2,292,000	1,870,000
300	3,022,000				3,004,000			2,963,000		2,819,000		2,579,000	2,213,000
325	3,262,000				3,245,000			3,208,000		3,076,000		2,858,000	2,532,000
350	3,504,000				3,487,000			3,453,000		3,330,000		3,130,000	2,836,000
375	3,744,000				3,729,000			3,697,000		3,583,000		3,397,000	3,128,000
400	3,985,000				3,971,000			3,932,000		3,834,000		3,661,000	3,412,000

CAPACITY, IN CUBIC FEET, OF 3″ PIPE LINE 4 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	124,000	....	....	....	....	....	....	....	....	....	....	....	....
20	232,000	203,000	149,000	....	....	....	....	....	....	....	....	....	....
30	336,000	311,000	278,000	235,000	166,000	....	....	....	....	....	....	....	....
40	425,000	407,000	383,000	352,000	314,000	262,000	....	....	....	....	....	....	....
50	513,000	498,000	479,000	455,000	425,000	390,000	287,000	....	....	....	....	....	....
60	601,000	587,000	572,000	551,000	....	498,000	424,000	311,000	....	....	....	....	....
70	686,000	....	....	644,000	....	599,000	538,000	454,000	....	....	....	....	....
80	771,000	....	....	734,000	....	696,000	644,000	575,000	....	....	....	....	....
90	857,000	....	....	823,000	....	789,000	760,000	703,000	449,000	....	....	....	....
100	942,000	....	....	910,000	....	877,000	831,000	789,000	595,000	....	....	....	....
125	1,152,000	....	....	....	1,116,000	....	1,070,000	1,031,000	891,000	663,000	....	....	....
150	1,362,000	....	....	....	1,331,000	....	1,293,000	1,261,000	1,150,000	983,000	889,000	....	....
175	1,570,000	....	....	....	1,544,000	....	....	1,484,000	1,391,000	1.255,000	1,067,000	783,000	....
200	1,780,000	....	....	....	1,757,000	....	....	1,703,000	1,624,000	1,511,000	1,357,000	1,146,000	....
225	1,988,000	....	....	....	1,962,000	....	....	1,920,000	....	1,746,000	1,620,000	1,446,000	881,000
250	2,197,000	....	....	....	2,178,000	....	....	2,136,000	....	1,985,000	1,871,000	1,724,000	1,288,000
275	2,405,000	....	....	....	2,388,000	....	....	2,350,000	....	2,213,000	....	1,983,000	1,618,000
300	2,614,000	....	....	....	2,598,000	....	....	2,562,000	....	2,439,000	....	2,231,000	1,914,000
325	2,822,000	....	....	....	2,807,000	....	....	2,775,000	....	2,661,000	....	2,472,000	2,190,000
350	3,031,000	....	....	....	3,017,000	....	....	2,987,000	....	2,880,000	....	2,707,000	2,453,000
375	3,239,000	....	....	....	3,225,000	....	....	3,198,000	....	3,099,000	....	2,938,000	2,706,000
400	3,446,000	....	....	....	3,435,000	....	....	3,401,000	....	3,316,000	....	3,166,000	2,952,000

CAPACITY, IN CUBIC FEET, OF 3″ PIPE LINE 5 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	111,000												
20	207,000	181,000	133,000										
30	300,000	277,000	248,000	210,000	148,000								
40	380,000	363,000	342,000	314,000	280,000	234,000							
50	458,000	445,000	428,000	406,000	380,000	348,000	256,000						
60	536,000	524,000	510,000	492,000	470,000	445,000	378,000						
70	613,000			575,000		535,000	481,000	406,000					
80	689,000			655,000		621,000	575,000	513,000					
90	765,000			735,000		704,000	663,000	612,000	400,000				
100	841,000			813,000		783,000	742,000	704,000	531,000				
125	1,029,000				996,000		955,000	920,000	795,000	592,000			
150	1,216,000				1,188,000		1,155,000	1,126,000	1,026,000	878,000	794,000		
175	1,402,000				1,378,000			1,325,000	1,242,000	1,121,000	953,000	699,000	
200	1,589,000				1,568,000			1,521,000	1,450,000	1,349,000	1,211,000	1,023,000	
225	1,775,000				1,752,000			1,715,000		1,559,000	1,447,000	1,291,000	787,000
250	1,961,000				1,945,000			1,907,000		1,773,000	1,670,000	1,539,000	1,150,000
275	2,148,000				2,132,000			2,098,000		1,976,000		1,770,000	1,444,000
300	2,334,000				2,320,000			2,288,000		2,177,000		1,992,000	1,709,000
325	2,520,000				2,506,000			2,477,000		2,376,000		2,207,000	1,955,000
350	2,706,000				2,693,000			2,667,000		2,572,000		2,417,000	2,190,000
375	2,892,000				2,880,000			2,855,000		2,767,000		2,623,000	2,416,000
400	3,077,000				3,067,000			3,036,000		2,961,000		2,827,000	2,635,000

CAPACITY, IN CUBIC FEET, OF 3″ PIPE LINE 7 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	94,000												
20	175,000	153,000	112,000										
30	254,000	234,000	210,000	177,000	125,000								
40	321,000	307,000	289,000	266,000	237,000	198,000							
50	387,000	376,000	362,000	343,000	321,000	294,000	217,000						
60	453,000	443,000	431,000	416,000		376,000	320,000						
70	518,000			486,000		452,000	406,000	343,000					
80	582,000			554,000		525,000	486,000	434,000					
90	647,000			621,000		595,000	561,000	517,000	338,000				
100	711,000			687,000		662,000	627,000	595,000	449,000				
125	869,000				842,000		807,000	778,000	672,000	500,000			
150	1,028,000				1,004,000		976,000	952,000	867,000	742,000	671,000		
175	1,185,000				1,165,000			1,120,000	1,049,000	947,000	805,000	591,000	
200	1,343,000				1,326,000			1,285,000	1,225,000	1,140,000	1,024,000	865,000	
225	1,500,000				1,481,000			1,449,000		1,317,000	1,223,000	1,092,000	665,000
250	1,658,000				1,644,000			1,612,000		1,498,000	1,412,000	1,301,000	972,000
275	1,815,000				1,802,000			1,773,000		1,670,000		1,496,000	1,221,000
300	1,973,000				1,961,000			1,934,000		1,840,000		1,683,000	1,444,000
325	2,130,000				2,118,000			2,094,000		2,008,000		1,865,000	1,653,000
350	2,287,000				2,276,000			2,254,000		2,174,000		2,043,000	1,851,000
375	2,444,000				2,434,000			2,413,000		2,339,000		2,217,000	2,042,000
400	2,601,000				2,592,000			2,566,000		2,502,000		2,389,000	2,227,000

CAPACITY, IN CUBIC FEET, OF 3″ PIPE LINE 10 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	78,000												
20	147,000	128,000	94,000										
30	213,000	196,000	176,000	148,000	105,000								
40	269,000	257,000	242,000	223,000	198,000	166,000							
50	325,000	315,000	303,000	288,000	269,000	246,000	182,000						
60	380,000	372,000	362,000	348,000	333,000	315,000	268,000	196,000					
70	431,000			407,000		379,000	341,000	287,000					
80	488,000			464,000		440,000	407,000	364,000					
90	542,000			521,000		449,000	470,000	434,000	284,000				
100	596,000			576,000		555,000	526,000	499,000	376,000				
125	729,000				706,000		677,000	652,000	564,000	419,000			
150	862,000				842,000		818,000	798,000	727,000	622,000	563,000		
175	994,000				977,000			939,000	880,000	794,000	675,000	495,000	
200	1,126,000				1,112,000			1,078,000	1,027,000	956,000	853,000	725,000	
225	1,258,000				1,242,000			1,215,000		1,105,000	1,025,000	915,000	557,000
250	1,310,000				1,378,000			1,352,000		1,256,000	1,184,000	1,091,000	815,000
275	1,522,000				1,511,000			1,487,000		1,401,000		1,255,000	1,024,000
300	1,654,000				1,644,000			1,622,000		1,543,000		1,412,000	1,211,000
325	1,786,000				1,776,000			1,756,000		1,684,000		1,564,000	1,386,000
350	1,918,000				1,909,000			1,890,000		1,823,000		1,713,000	1,552,000
375	2,049,000				2,041,000			2,024,000		1,961,000		1,859,000	1,712,000
400	2,181,000				2,174,000			2,152,000		2,098,000		2,004,000	1,868,000

CAPACITY, IN CUBIC FEET, OF 3″ PIPE LINE 15 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	64,000	...	...	...	...	...	...	...	...	...	...	...	...
20	120,000	105,000	77,000	...	...	...	...	...	...	...	...	...	...
30	174,000	160,000	143,000	121,000	85,000	...	...	...	...	...	...	...	...
40	220,000	210,000	198,000	182,000	162,000	135,000	...	...	...	...	...	...	...
50	265,000	257,000	247,000	235,000	220,000	201,000	148,000	...	...	...	...	...	...
60	310,000	303,000	295,000	284,000	272,000	257,000	219,000	160,000	...	...	...	...	...
70	355,000	...	...	333,000	...	309,000	278,000	235,100	...	...	...	...	...
80	398,000	...	...	379,000	...	359,000	333,000	297,000	...	...	...	...	...
90	443,000	...	...	425,000	...	407,000	384,000	354,000	232,000	...	...	...	...
100	486,000	...	...	470,000	...	453,000	429,000	407,000	307.000	...	...	...	...
125	595,000	...	...	...	576,000	...	553,000	532,000	460,000	342,000	...	...	...
150	704,000	...	...	...	688,000	...	668,000	652,000	594,000	508,000	459,000	...	...
175	811,000	...	...	...	798,000	...	...	767,000	719,000	648,000	551,000	404,000	...
200	920,000	...	...	...	908,000	...	...	880,000	839,000	780,000	701,000	592,000	...
225	1,027,000	...	...	...	1,014,000	...	...	992,000	...	902,000	837,000	747,000	455,000
250	1,135,000	...	...	...	1,126,000	...	...	1,104,000	...	1,026,000	967,000	891,000	665,000
275	1,243,000	...	...	...	1,234,000	...	...	1,214,000	...	1,144,000	...	1,025,000	836,000
300	1,351,000	...	...	...	1,343,000	...	...	1,324,000	...	1,260,000	...	1,153,000	989,000
325	1,458,000	...	...	...	1,451,000	...	...	1,434,000	...	1,375,000	...	1,277,000	1,132,000
350	1,566,000	...	...	...	1,559,000	...	...	1,543,000	...	1,488,000	...	1,399,000	1,267,000
375	1,674,000	...	...	...	1,667,000	...	...	1,653,000	...	1,601,000	...	1,518,000	1,398,000
400	1,781,000	...	...	...	1,775,000	...	...	1,757,000	...	1,713,000	...	1,635,000	1,525,000

CAPACITY, IN CUBIC FEET, OF 3″ PIPE LINE 25 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	49,000	....	....	....	....	....	....	....	....	....	....	....	....
20	93,000	81,000	59,000	....	....	....	....	....	....	....	....	....	....
30	134,000	124,000	111,000	94,000	66,000	....	....	....	....	....	....	....	....
40	170,000	162,000	153,000	141,000	125,000	105,000	....	....	....	....	....	....	....
50	205,000	199,000	191,000	182,000	170,000	155,000	115,000	....	....	....	....	....	....
60	240,000	235,000	228,000	220,000	210,000	199,000	169,000	124,000	....	....	....	....	....
70	274,000	....	....	257,000	....	239,000	215,000	181,000	....	....	....	....	....
80	308,000	....	....	293,000	....	278,000	257,000	230,000	....	....	....	....	....
90	342,000	....	....	329,000	....	315,000	297,000	274,000	179,000	....	....	....	....
100	376,000	....	....	364,000	....	350,000	332,000	315,000	238,000	....	....	....	....
125	460,000	....	....	....	446,000	....	428,000	412,000	356,000	265,000	....	....	....
150	544,000	....	....	....	532,000	....	517,000	504,000	459,000	393,000	355,000	....	....
175	628,000	....	....	....	617,000	....	....	593,000	556,000	502,000	427,000	313,000	....
200	712,000	....	....	....	702,000	....	....	681,000	649,000	604,000	542,000	458,000	....
225	795,000	....	....	....	784,000	....	....	768,000	....	698,000	648,000	578,000	352,000
250	878,000	....	....	....	871,000	....	....	854,000	....	794,000	748,000	689,000	515,000
275	962,000	....	....	....	955,000	....	....	939,000	....	885,000	....	793,000	647,000
300	1,045,000	....	....	....	1,039,000	....	....	1,025,000	....	975,000	....	892,000	765,000
325	1,128,000	....	....	....	1,122,000	....	....	1,109,000	....	1,064,000	....	988,000	876,000
350	1,212,000	....	....	....	1,206,000	....	....	1,194,000	....	1,152,000	....	1,082,000	981,000
375	1,295,000	....	....	....	1,290,000	....	....	1,279,000	....	1,239,000	....	1,175,000	1,082,000
400	1,378,000	....	....	....	1,373,000	....	....	1,360,000	....	1,326,000	....	1,266,000	1,180,000

CAPACITY, IN CUBIC FEET, OF 4″ PIPE LINE 1 MILE LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	515,000												
20	962,000	842,000	618,000										
30	1,392,000	1,285,000	1,151,000	972,000	687,000								
40	1,759,000	1,684,000	1,584,000	1,457,000	1,299,000	1,086,000							
50	2,124,000	2,062,000	1,983,000	1,883,000	1,759,000	1,612,000	1,189,000						
60	2,485,000	2,430,000	2,364,000	2,278,000		2,062,000	1,752,000	1,285,000					
70	2,839,000			2,663,000		2,478,000	2,227,000	1,880,000					
80	3,189,000			3,035,000		2,876,000	2,663,000	2,378,000					
90	3,543,000			3,402,000		3,261,000	3,072,000	2,835,000	1,856,000				
100	3,894,000			3,763,000		3,626,000	3,437,000	3,261,000	2,461,000				
125	4,763,000				4,612,000		4,423,000	4,262,000	3,684,000	2,742,000			
150	5,630,000				5,502,000		5,348,000	5,214,000	4,753,000	4,066,000	3,677,000		
175	6,492,000				6,382,000			6,135,000	5,750,000	5,190,000	4,413,000	3,237,000	
200	7,359,000				7,262,000			7,042,000	6,712,000	6,245,000	5,607,000	4,739,000	
225	8,218,000				8,111,000			7,939,000		7,218,000	6,699,000	5,980,000	3,643,000
250	9,081,000				9,005,000			8,830,000		8,208,000	7,733,000	7,128,000	5,324,000
275	9,943,000				9,871,000			9,712,000		9,149,000		8,197,000	6,688,000
300	10,806,000				10,741,000			10,593,000		10,081,000		9,222,000	7,912,000
325	11,665,000				11,603,000			11,469,000		10,999,000		10,218,000	9,053,000
350	12,528,000				12,470,000			12,346,000		11,906,000		11,191,000	10,139,000
375	13,387,000				13,332,000			13,219,000		12,810,000		12,147,000	11,184,000
400	14,247,000				14,199,000			14,058,000		13,707,000		13,088,000	12,202,000

CAPACITY, IN CUBIC FEET, OF 4″ PIPE LINE 2 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	365,000												
20	682,000	597,000	438,000										
30	987,000	911,000	816,000	689,000	487,000								
40	1,248,000	1,194,000	1,123,000	1,033,000	921,000	770,000							
50	1,506,000	1,462,000	1,406,000	1,335,000	1,248,000	1,143,000	843,000						
60	1,762,000	1,723,000	1,677,000	1,616,000		1,462,000	1,243,000	911,000					
70	2,013,000			1,889,000		1,757,000	1,579,000	1,333,000					
80	2,262,000			2,152,000		2,040,000	1,889,000	1,686,000					
90	2,513,000			2,413,000		2,313,000	2,179,000	2,011,000	1,316,000				
100	2,762,000			2,669,000		2,571,000	2,437,000	2,313,000	1,745,000				
125	3,378,000				3,271,000		3,137,000	3,022,000	2,613,000	1,945,000			
150	3,993,000				3,902,000		3,793,000	3,698,000	3,371,000	2,883,000	2,608,000		
175	4,605,000				4,526,000			4,351,000	4,078,000	3,681,000	3,130,000	2,296,000	
200	5,219,000				5,151,000			4,995,000	4,761,000	4,429,000	3,978,000	3,361,000	
225	5,828,000				5,753,000			5,631,000		5,119,000	4,751,000	4,241,000	2,584,000
250	6,440,000				6,387,000			6,262,000		5,821,000	5,485,000	5,055,000	3,776,000
275	7,052,000				7,001,000			6,889,000		6,489,000		5,814,000	4,743,000
300	7,664,000				7,618,000			7,513,000		7,150,000		6,540,000	5,611,000
325	8,273,000				8,230,000			8,134,000		7,800,000		7,247,000	6,421,000
350	8,885,000				8,844,000			8,756,000		8,444,000		7,937,000	7,191,000
375	9,495,000				9,456,000			9,375,000		9,085,000		8,615,000	7,932,000
400	10,104,000				10,070,000			9,970,000		9,721,000		9,283,000	8,654,000

CAPACITY, IN CUBIC FEET, OF 4″ PIPE LINE 3 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	298,000	....	....	....	....	....	....	....	....	....	....	....	....
20	556,000	486,000	357,000	....	....	....	....	....	....	....	....	....	....
30	804,000	743,000	665,000	562,000	397,000	....	....	....	....	....	....	....	....
40	1,017,000	973,000	916,000	842,000	751,000	627,000	....	....	....	....	....	....	....
50	1,227,000	1,192,000	1,146,000	1,088,000	1,017,000	931,000	687,000	....	....	....	....	....	....
60	1,436,000	1,404,000	1,367,000	1,317,000	....	1,192,000	1,013,000	743,000	....	....	....	....	....
70	1,641,000	....	....	1,539,000	....	1,432,000	1,287,000	1,086,000	....	....	....	....	....
80	1,843,000	....	....	1,754,000	....	1,663,000	1,539,000	1,375,000	....	....	....	....	....
90	2,048,000	....	....	1,967,000	....	1,885,000	1,776,000	1,639,000	1,072,000	....	....	....	....
100	2,251,000	....	....	2,175,000	....	2,096,000	1,987,000	1,885,000	1,422,000	....	....	....	....
125	2,753,000	....	....	....	2,666,000	....	2,557,000	2,463,000	2,130,000	1,585,000	....	....	....
150	3,254,000	....	....	....	3,181,000	....	3,091,000	3,014,000	2,748,000	2,350,000	2,126,000	....	....
175	3,753,000	....	....	....	3,689,000	....	....	3,546,000	3,324,000	3,000,000	2,551,000	1,871,000	....
200	4,254,000	....	....	....	4,198,000	....	....	4,071,000	3,880,000	3,610,000	3,242,000	2,740,000	....
225	4,750,000	....	....	....	4,689,000	....	....	4,589,000	....	4,172,000	3,872,000	3,457,000	2,106,000
250	5,249,000	....	....	....	5,205,000	....	....	5,104,000	....	4,744,000	4,470,000	4,121,000	3,077,000
275	5,748,000	....	....	....	5,706,000	....	....	5,615,000	....	5,289,000	....	4,738,000	3,866,000
300	6,247,000	....	....	....	6,209,000	....	....	6,123,000	....	5,827,000	....	5,331,000	4,574,000
325	6,743,000	....	....	....	6,708,000	....	....	6,630,000	....	6,358,000	....	5,907,000	5,233,000
350	7,242,000	....	....	....	7,208,000	....	....	7,137,000	....	6,882,000	....	6,469,000	5,861,000
375	7,739,000	....	....	....	7,707,000	....	....	7,642,000	....	7,405,000	....	7,022,000	6,465,000
400	8,236,000	....	....	....	8,208,000	....	....	8,126,000	....	7,924,000	....	7,566,000	7,053,000

CAPACITY, IN CUBIC FEET, OF 4″ PIPE LINE 4 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	257,000	...	...	...	...	...	...	...	...	...	...	...	...
20	481,000	421,000	309,000	...	...	...	...	...	...	...	...	...	...
30	696,000	642,000	575,000	486,000	343,000	...	...	...	...	...	...	...	...
40	879,000	842,000	792,000	728,000	649,000	543,000	...	...	...	...	...	...	...
50	1,062,000	1,031,000	991,000	941,000	879,000	806,000	594,000	...	...	...	...	...	...
60	1,242,000	1,215,000	1,182,000	1,139,000	...	1,031,000	876,000	642,000	...	...	...	...	...
70	1,419,000	...	...	1,331,000	...	1,239,000	1,113,000	940,000	...	...	...	...	...
80	1,594,000	...	...	1,517,000	...	1,438,000	1,331,000	1,189,000	...	...	...	...	...
90	1,771,000	...	...	1,701,000	...	1,630,000	1,536,000	1,417,000	928,000	...	...	...	...
100	1,947,000	...	...	1,881,000	...	1,813,000	1,718,000	1,630,000	1,230,000	...	...	...	...
125	2,381,000	...	...	...	2,306,000	...	2,211,000	2,131,000	1,842,000	1,371,000	...	...	...
150	2,815,000	...	...	...	2,751,000	...	2,674,000	2,607,000	2,376,000	2,033,000	1,838,000	...	...
175	3,246,000	...	...	...	3,191,000	...	...	3,067,000	2,875,000	2,595,000	2,206,000	1,618,000	...
200	3,679,000	...	...	...	3,631,000	...	...	3,521,000	3,356,000	3,122,000	2,804,000	2,369,000	...
225	4,109,000	...	...	...	4,055,000	...	...	3,969,000	...	3,609,000	3,349,000	2,990,000	1,821,000
250	4,540,000	...	...	...	4,502,000	...	...	4,415,000	...	4,104,000	3,866,000	3,561,000	2,662,000
275	4,971,000	...	...	...	4,935,000	...	...	4,856,000	...	4,574,000	...	4,098,000	3,341,000
300	5,403,000	...	...	...	5,370,000	...	...	5,296,000	...	5,040,000	...	4,611,000	3,956,000
325	5,832,000	...	...	...	5,801,000	...	...	5,734,000	...	5,499,000	...	5,109,000	4,526,000
350	6,264,000	...	...	...	6,235,000	...	...	6,173,000	...	5,953,000	...	5,595,000	5,069,000
375	6,693,000	...	...	...	6,666,000	...	...	6,609,000	...	6,405,000	...	6,073,000	5,592,000
400	7,123,000	...	...	...	7,099,000	...	...	7,029,000	...	6,853,000	...	6,544,000	6,101,000

CAPACITY, IN CUBIC FEET, OF 4″ PIPE LINE 5 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	230,000	....	....	....	....	....	....	....	....	....	....	....	....
20	429,000	375,000	276,000	....	....	....	....	....	....	....	....	....	....
30	621,000	573,000	514,000	434,000	306,000	....	....	....	....	....	....	....	....
40	785,000	751,000	707,000	659,000	580,000	484,000	....	....	....	....	....	....	....
50	948,000	920,000	885,000	840,000	785,000	719,000	530,000	....	....	....	....	....	....
60	1,109,000	1,084,000	1,055,000	1,017,000	972,000	920,000	782,000	573,000	....	....	....	....	....
70	1,267,000	....	....	1,189,000	....	1,106,000	994,000	839,000	....	....	....	....	....
80	1,424,000	....	....	1,354,000	....	1,284,000	1,189,000	1,061,000	....	....	....	....	....
90	1,582,000	....	....	1,519,000	....	1,456,000	1,371,000	1,265,000	828,000	....	....	....	....
100	1,738,000	....	....	1,680,000	....	1,618,000	1,531,000	1,456,000	1,098,000	....	....	....	....
125	2,126,000	....	....	....	2,059,000	....	1,974,000	1,902,000	1,644,000	1,224,000	....	....	....
150	2,513,000	....	....	....	2,456,000	....	2,387,000	2,327,000	2,122,000	1,815,000	1,641,000	....	....
175	2,898,000	....	....	....	2,849,000	....	....	2,739,000	2,567,000	2,317,000	1,970,000	1,445,000	....
200	3,285,000	....	....	....	3,242,000	....	....	3,144,000	2,996,000	2,788,000	2,501,000	2,116,000	....
225	3,668,000	....	....	....	3,621,000	....	....	3,544,000	....	3,222,000	2,990,000	2,670,000	1,626,000
250	4,054,000	....	....	....	4,020,000	....	....	3,942,000	....	3,664,000	3,452,000	3,182,000	2,376,000
275	4,439,000	....	....	....	4,407,000	....	....	4,336,000	....	4,084,000	....	3,659,000	2,986,000
300	4,824,000	....	....	....	4,795,000	....	....	4,729,000	....	4,500,000	....	4,117,000	3,532,000
325	5,208,000	....	....	....	5,180,000	....	....	5,120,000	....	4,910,000	....	4,562,000	4,041,000
350	5,593,000	....	....	....	5,567,000	....	....	5,511,000	....	5,315,000	....	4,996,000	4,526,000
375	5,976,000	....	....	....	5,952,000	....	....	5,901,000	....	5,719,000	....	5,422,000	4,993,000
400	6,360,000	....	....	....	6,339,000	....	....	6,276,000	....	6,119,000	....	5,843,000	5,447,000

CAPACITY, IN CUBIC FEET, OF 4″ PIPE LINE 7 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	194,000												
20	363,000	317,000	233,000										
30	525,000	485,000	434,000	367,000	259,000								
40	664,000	635,000	597,000	549,000	490,000	409,000							
50	801,000	778,000	748,000	710,000	664,000	608,000	448,000						
60	937,000	917,000	892,000	859,000	822,000	778,000	661,000	485,000					
70	1,071,000			1,005,000		935,000	840,000	709,000					
80	1,203,000			1,145,000		1,085,000	1,005,000	897,000					
90	1,337,000			1,284,000		1,230,000	1,159,000	1,070,000	700,000				
100	1,469,000			1,420,000		1,368,000	1,297,000	1,230,000	928,000				
125	1,797,000				1,740,000		1,669,000	1,608,000	1,390,000	1,035,000			
150	2,124,000				2,076,000		2,018,000	1,967,000	1,793,000	1,534,000	1,387,000		
175	2,450,000				2,408,000			2,315,000	2,170,000	1,958,000	1,665,000	1,221,000	
200	2,777,000				2,740,000			2,657,000	2,533,000	2,356,000	2,116,000	1,788,000	
225	3,101,000				3,061,000			2,996,000		2,723,000	2,528,000	2,256,000	1,374,000
250	3,426,000				3,398,000			3,332,000		3,097,000	2,918,000	2,690,000	2,009,000
275	3,752,000				3,725,000			3,665,000		3,452,000		3,095,000	2,521,000
300	4,078,000				4,053,000			3,997,000		3,804,000		3,480,000	2,985,000
325	4,402,000				4,379,000			4,328,000		4,150,000		3,856,000	3,416,000
350	4,727,000				4,705,000			4,659,000		4,493,000		4,223,000	3,826,000
375	5,052,000				5,031,000			4,988,000		4,834,000		4,583,000	4,220,000
400	5,376,000				5,358,000			5,305,000		5,172,000		4,939,000	4,604,000

CAPACITY, IN CUBIC FEET, OF 4″ PIPE LINE 10 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	163,000	....	....	....	....	....	....	....	....	....	....	....	....
20	304,000	266,000	195,000	....	....	....	....	....	....	....	....	....	....
30	440,000	406,000	364,000	307,000	217,000	....	....	....	....	....	....	....	....
40	556,000	533,000	501,000	461,000	411,000	343,000	....	....	....	....	....	....	....
50	672,000	652,000	627,000	596,000	556,000	510,000	376,000	....	....	....	....	....	....
60	786,000	769,000	748,000	721,000	689,000	652,000	554,000	406,000	....	....	....	....	....
70	898,000	....	....	843,000	....	784,000	704,000	595,000	....	....	....	....	....
80	1,009,000	....	....	960,000	....	910,000	843,000	752,000	....	....	....	....	....
90	1,121,000	....	....	1,076,000	....	1,032,000	972,000	897,000	587,000	....	....	....	....
100	1,232,000	....	....	1,191,000	....	1,147,000	1,087,000	1,032,000	778,000	....	....	....	....
125	1,507,000	....	....	....	1,459,000	....	1,399,000	1,348,000	1,166,000	868,000	....	....	....
150	1,781,000	....	....	....	1,741,000	....	1,692,000	1,650,000	1,504,000	1,286,000	1,163,000	....	....
175	2,054,000	....	....	....	2,020,000	....	....	1,941,000	1,819,000	1,642,000	1,396,000	1,024,000	....
200	2,328,000	....	....	....	2,298,000	....	....	2,228,000	2,124,000	1,976,000	1,775,000	1,500,000	....
225	2,600,000	....	....	....	2,566,000	....	....	2,512,000	....	2,284,000	2,119,000	1,892,000	1,152,000
250	2,873,000	....	....	....	2,850,000	....	....	2,794,000	....	2,597,000	....	2,256,000	1,685,000
275	3,147,000	....	....	....	3,124,000	....	....	3,074,000	....	2,895,000	....	2,594,000	2,116,000
300	3,420,000	....	....	....	3,399,000	....	....	3,352,000	....	3,190,000	....	2,918,000	2,504,000
325	3,691,000	....	....	....	3,672,000	....	....	3,629,000	....	3,480,000	....	3,234,000	2,865,000
350	3,965,000	....	....	....	3,946,000	....	....	3,907,000	....	3,768,000	....	3,541,000	3,209,000
375	4,236,000	....	....	....	4,219,000	....	....	4,183,000	....	4,054,000	....	3,844,000	3,539,000
400	4,508,000	....	....	....	4,502,000	....	....	4,449,000	....	4,338,000	....	4,142,000	3,861,000

CAPACITY, IN CUBIC FEET, OF 4″ PIPE LINE 15 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	133,000												
20	248,000	217,000	159,000										
30	359,000	332,000	297,000	251,000	177,000								
40	454,000	435,000	409,000	376,000	335,000	280,000							
50	548,000	532,000	512,000	486,000	454,000	416,000	307,000						
60	642,000	628,000	611,000	588,000	563,000	532,000	453,000	332,000					
70	733,000			688,000		640,000	575,000	485,000					
80	824,000			784,000		743,000	688,000	614,000					
90	915,000			879,000		842,000	794,000	732,000	479,000				
100	1,006,000			972,000		937,000	883,000	842,000	636,000				
125	1,231,000				1,192,000		1,143,000	1,101,000	952,000				
150	1,455,000				1,422,000		1,382,000	1,347,000	1,228,000	1,050,000	950,000		
175	1,677,000				1,649,000			1,585,000	1,486,000	1,341,000	1,140,000	836,000	
200	1,901,000				1,876,000			1,820,000	1,734,000	1,614,000	1,449,000	1,224,000	
225	2,123,000				2,076,000			2,051,000		1,865,000	1,731,000	1,545,000	941,000
250	2,346,000				2,327,000			2,282,000		2,121,000		1,842,000	1,375,000
275	2,569,000				2,551,000			2,510,000		2,364,000		2,118,000	1,728,000
300	2,792,000				2,775,000			2,737,000		2,605,000		2,383,000	2,044,000
325	3,014,000				2,998,000			2,964,000		2,842,000		2,640,000	2,339,000
350	3,237,000				3,222,000			3,190,000		3,061,000		2,892,000	2,620,000
375	3,459,000				3,445,000			3,416,000		3,310,000		3,139,000	2,890,000
400	3,682,000				3,676,000			3,633,000		3,542,000		3,382,000	3,153,000

CAPACITY, IN CUBIC FEET, OF 4″ PIPE LINE 25 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	103,000	....	....	....	....	....	....	....	....	....	....	....	....
20	192,000	168,000	123,000	....	....	....	....	....	....	....	....	....	....
30	278,000	257,000	230,000	194,000	137,000	....	....	....	....	....	....	....	....
40	351,000	336,000	316,000	291,000	259,000	217,000	....	....	....	....	....	....	....
50	424,000	412,000	396,000	376,000	351,000	322,000	237,000	....	....	....	....	....	....
60	496,000	485,000	472,000	455,000	435,000	412,000	350,000	257,000	....	....	....	....	....
70	567,000	....	....	532,000	....	494,000	445,000	376,000	....	....	....	....	....
80	637,000	....	....	606,000	....	575,000	532,000	475,000	....	....	....	....	....
90	708,000	....	....	680,000	....	652,000	614,000	567,000	371,000	....	....	....	....
100	778,000	....	....	752,000	741,000	725,000	687,000	652,000	492,000	....	....	....	....
125	952,000	....	....	....	922,000	....	884,000	852,000	736,000	548,000	....	....	....
150	1,125,000	....	....	....	1,100,000	....	1,069,000	1,042,000	950,000	813,000	735,000	....	....
175	1,298,000	....	....	....	1,276,000	....	....	1.227,000	1,150,000	1,037,000	882,000	647,000	....
200	1,471,000	....	....	....	1,452,000	....	....	1,408,000	1,342,000	1,249,000	1,121,000	947,000	....
225	1,643,000	....	....	....	1,622,000	....	....	1,587,000	....	1,443,000	1,339,000	1,196,000	728,000
250	1,816,000	....	....	....	1,800,000	....	....	1,765,000	....	1,641,000	1,546,000	1,425,000	1,064,000
275	1,988,000	....	....	....	1,974,000	....	....	1,942,000	....	1,829,000	....	1,639,000	1,337,000
300	2,161,000	....	....	....	2,148,000	....	....	2,118,000	....	2,016,000	....	1,844,000	1,582,000
325	2,333,000	....	....	....	2,320,000	....	....	2,293,000	....	2,199,000	....	2,043,000	1,810,000
350	2,505,000	....	....	....	2,493,000	....	....	2,469,000	....	2,381,000	....	2,238,000	2,027,000
375	2,677,000	....	....	....	2,666,000	....	....	2,643,000	....	2,561,000	....	2,429,000	2,236,000
400	2,849,000	....	....	....	2,839,000	....	....	2,811,000	....	2,741,000	....	2,617,000	2,440,000

CAPACITY, IN CUBIC FEET, OF 4″ PIPE LINE 35 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	87,000												
20	162,000	142,000	104,000										
30	235,000	217,000	194,000	164,000	116,000								
40	297,000	284,000	267,000	246,000	219,000	183,000							
50	358,000	348,000	335,000	318,000	297,000	272,000	200,000						
60	419,000	410,000	399,000	385,000	368,000	348,000	296,000	217,000					
70	479,000			450,000		418,000	376,000	317,000					
80	538,000			512,000		486,000	450,000	401,000					
90	598,000			574,000		551,000	519,000	479,000					
100	657,000			635,000	625,000	612,000	580,000	551,000	415,000				
125	804,000				779,000		747,000	720,000	622,000	463,000			
150	951,000				929,000		903,000	880,000	803,000	686,000	621,000		
175	1,096,000				1,078,000			1,036,000	971,000	876,000	745,000	547,000	
200	1,243,000				1,227,000			1,189,000	1,134,000	1,055,000	947,000	800,000	
225	1,388,000				1,370,000			1,341,000		1,219,000	1,131,000	1,010,000	615,000
250	1,534,000				1,521,000			1,491,000		1,386,000	1,306,000	1,201,000	899,000
275	1,679,000				1,667,000			1,641,000		1,545,000		1,384,000	1,130,000
300	1,825,000				1,814,000			1,789,000		1,703,000		1,558,000	1,336,000
325	1,970,000				1,960,000			1,937,000		1,858,000		1,726,000	1,529,000
350	2,116,000				2,106,000			2,085,000		2,011,000		1,890,000	1,713,000
375	2,261,000				2,252,000			2,233,000		2,164,000		2,052,000	1,889,000
400	2,407,000				2,398,000			2,375,000		2,315,000		2,211,000	2,061,000

CAPACITY, IN CUBIC FEET, OF 4″ PIPE LINE 50 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	72,000	...	...	...	...	...	...	...	...	...	...	...	...
20	136,000	119,000	87,000	...	...	...	...	...	...	...	...	...	...
30	196,000	181,000	162,000	137,000	97,000	...	...	...	...	...	...	...	...
40	248,000	238,000	224,000	206,000	183,000	153,000	...	...	...	...	...	...	...
50	300,000	291,000	280,000	266,000	248,000	228,000	168,000	...	...	...	...	...	...
60	351,000	343,000	334,000	322,000	308,000	291,000	247,000	181,000	...	...	...	...	...
70	401,000	...	...	376,000	...	350,000	315,000	265,000	...	...	...	...	...
80	451,000	...	...	429,000	...	406,000	376,000	336,000	...	...	...	...	...
90	501,000	...	...	481,000	...	461,000	434,000	401,000	262,000	...	...	...	...
100	550,000	...	...	532,000	...	512,000	486,000	461,000	348,000	...	...	...	...
125	673,000	...	...	...	652,000	...	625,000	602,000	521,000	387,000	...	...	...
150	796,000	...	...	...	778,000	...	756,000	737,000	672,000	575,000	520,000	...	...
175	918,000	...	...	...	902,000	...	...	867,000	813,000	734,000	624,000	458,000	...
200	1,040,000	...	...	...	1,027,000	...	...	996,000	949,000	883,000	793,000	670,000	...
225	1,162,000	...	...	...	1,147,000	...	...	1,123,000	...	1,021,000	947,000	845,000	515,000
250	1,284,000	...	...	...	1,273,000	...	...	1,249,000	...	1,161,000	1,093,000	1,008,000	753,000
275	1,406,000	...	...	...	1,396,000	...	...	1,374,000	...	1,294,000	...	1,159,000	946,000
300	1,528,000	...	...	...	1,519,000	...	...	1,498,000	...	1,426,000	...	1,304,000	1,119,000
325	1,650,000	...	...	...	1,641,000	...	...	1,622,000	...	1,555,000	...	1,445,000	1,280,000
350	1,772,000	...	...	...	1,763,000	...	...	1,746,000	...	1,684,000	...	1,583,000	1,434,000
375	1,893,000	...	...	...	1,885,000	...	...	1,869,000	...	1,812,000	...	1,718,000	1,582,000
400	2,015,000	...	...	...	2,008,000	...	...	1,988,000	...	1,938,000	...	1,851,000	1,726,000

CAPACITY, IN CUBIC FEET, OF 4″ PIPE LINE 70 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	61,000												
20	114,000	100,000	73,000										
30	166,000	153,000	137,000	116,000	82,000								
40	210,000	201,000	189,000	174,000	155,000	129,000							
50	253,000	246,000	236,000	224,000	210,000	192,000	142,000						
60	296,000	290,000	282,000	272,000	260,000	246,000	209,000	153,000					
70	339,000			318,000		295,000	266,000	224,000					
80	380,000			362,000		343,000	318,000	284,000					
90	423,000			406,000		389,000	366,000	338,000	221,000				
100	465,000			449,000	442,000	433,000	410,000	389,000	293,000				
125	568,000				550,060		528,000	509,000	440,000	327,000			
150	672,000				657,000		638,000	622,000	567,000	485,000	439,000		
175	775,000				762,000			732,000	686,000	619,000	527,000	386,000	
200	878,000				867,000			841,000	801,000	745,000	669,000	566,000	
225	981,000				968,000			948,000		862,000	800,000	714,000	435,000
250	1,084,000				1,075,000			1,054,000		980,000	923,000	851,000	635,000
275	1,187,000				1,178,000			1,160,000		1,092,000		979,000	798,000
300	1,290,000				1,282,000			1,265,000		1,203,000		1,101,000	944,000
325	1,393,000				1,385,000			1,369,000		1,313,000		1,220,000	1,081,000
350	1,496,000				1,489,000			1,474,000		1,421,000		1,336,000	1,210,000
375	1,598,000				1,592,000			1,578,000		1,529,000		1,450,000	1,335,000
400	1,701,000				1,695,000			1,678,000		1,637,000		1,563,000	1,457,000

CAPACITY, IN CUBIC FEET, OF 4″ PIPE LINE 100 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	51,000	...	...	...	...	...	...	...	...	...	...	...	...
20	96,000	84,000	61,000	...	...	...	...	...	...	...	...	...	...
30	139,000	128,000	115,000	97,000	68,000	...	...	...	...	...	...	...	...
40	175,000	168,000	158,000	145,000	129,000	108,000	...	...	...	...	...	...	...
50	212,000	206,000	198,000	188,000	175,000	161,000	118,000	...	...	...	...	...	...
60	248,000	242,000	236,000	227,000	217,000	206,000	175,000	128,000	...	...	...	...	...
70	283,000	...	...	266,000	...	247,000	222,000	188,000	...	...	...	...	...
80	318,000	...	...	303,000	...	287,000	266,000	237,000	...	...	...	...	...
90	354,000	...	...	340,000	...	326,000	307,000	283,000	185,000	...	...	...	...
100	389,000	...	...	376,000	...	362,000	343,000	326,000	246,000	...	...	...	...
125	476,000	...	...	...	461,000	...	442,000	426,000	368,000	274,000	...	...	...
150	562,000	...	...	...	550,000	...	534,000	521,000	475,000	406,000	367,000	...	...
175	649,000	...	...	...	638,000	...	...	613,000	575,000	518,000	441,000	323,000	...
200	735,000	...	...	...	726,000	...	...	704,000	671,000	624,000	560,000	473,000	...
225	821,000	...	...	...	811,000	...	...	793,000	...	721,000	669,000	598,000	364,000
250	908,000	...	...	...	900,000	...	...	882,000	...	820,000	773,000	712,000	532,000
275	994,000	...	...	...	987,000	...	...	971,000	...	914,000	...	819,000	668,000
300	1,080,000	...	...	...	1,074,000	...	...	1,059,000	...	1,008,000	...	922,000	791,000
325	1,166,000	...	...	...	1,160,000	...	...	1,146,000	...	1,099,000	...	1,021,000	905,000
350	1,252,000	...	...	...	1,246,000	...	...	1,234,000	...	1,190,000	...	1,119,000	1,013,000
375	1,338,000	...	...	...	1,333,000	...	...	1,321,000	...	1,280,000	...	1,214,000	1,118,000
400	1,424,000	...	...	...	1,419,000	...	...	1,405,000	...	1,370,000	...	1,308,000	1,220,000

CAPACITY, IN CUBIC FEET, OF 6″ PIPE LINE 1 MILE LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,436,000	....	....	....	....	....	....	....	....	....	....	....	....
20	2,681,000	2,346,000	1,723,000	....	....	....	....	....	....	....	....	....	....
30	3,878,000	3,581,000	3,207,000	2,710,000	1,915,000	....	....	....	....	....	....	....	....
40	4,902,000	4,692,000	4,414,000	4,060,000	3,619,000	3,026,000	....	....	....	....	....	....	....
50	5,917,000	5,745,000	5,525,000	5,247,000	4,902,000	4,491,000	3,313,000	....	....	....	....	....	....
60	6,923,000	6,770,000	6,588,000	6,348,000	....	5,745,000	4,883,000	3,581,000	....	....	....	....	....
70	7,900,000	....	....	7,421,000	....	6,904,000	6,205,000	5,238,000	....	....	....	....	....
80	8,886,000	....	....	8,455,000	....	8,015,000	7,421,000	6,626,000	....	....	....	....	....
90	9,872,000	....	....	9,480,000	....	9,087,000	8,560,000	7,900,000	5,171,000	....	....	....	....
100	10,849,000	....	....	10,485,000	....	10,102,000	9,576,000	9,087,000	6,856,000	....	....	....	....
125	13,272,000	....	....	....	12,850,000	....	12,324,000	11,874,000	10,265,000	7,641,000	....	....	....
150	15,685,000	....	....	....	15,331,000	....	14,900,000	14,526,000	13,243,000	11,328,000	10,246,000	....	....
175	18,089,000	....	....	....	17,782,000	....	....	17,093,000	16,020,000	14,459,000	12,295,000	9,020,000	....
200	20,502,000	....	....	....	20,234,000	....	....	19,621,000	18,701,000	17,399,000	15,628,000	13,205,000	....
225	22,896,000	....	....	....	22,599,000	....	....	22,120,000	....	20,109,000	18,663,000	16,662,000	10,150,000
250	25,299,000	....	....	....	25,089,000	....	....	24,600,000	....	22,867,000	21,546,000	19,860,000	14,833,000
275	27,703,000	....	....	....	27,502,000	....	....	27,061,000	....	25,491,000	....	22,838,000	18,634,000
300	30,106,000	....	....	....	29,925,000	....	....	29,513,000	....	28,086,000	....	25,692,000	22,043,000
325	32,500,000	....	....	....	32,328,000	....	....	31,955,000	....	30,643,000	....	28,469,000	25,223,000
350	34,904,000	....	....	....	34,741,000	....	....	34,396,000	....	33,171,000	....	31,179,000	28,249,000
375	37,298,000	....	....	....	37,145,000	....	....	36,829,000	....	35,689,000	....	33,841,000	31,160,000
400	39,692,000	....	....	....	39,558,000	....	....	39,165,000	....	38,189,000	....	36,465,000	33,994,000

CAPACITY, IN CUBIC FEET, OF 6″ PIPE LINE 2 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,018,000	....	....	....	....	....	....	....	....	....	....	....	....
20	1,901,000	1,663,000	1,222,000	....	....	....	....	....	....	....	....	....	....
30	2,750,000	2,540,000	2,275,000	1,921,000	1,358,000	....	....	....	....	....	....	....	....
40	3,477,000	3,327,000	3,130,000	2,879,000	2,567,000	2,146,000	....	....	....	....	....	....	....
50	4,197,000	4,074,000	3,918,000	3,721,000	3,477,000	3,185,000	2,349,000	....	....	....	....	....	....
60	4,910,000	4,801,000	4,672,000	4,502,000	....	4,074,000	3,463,000	2,540,000	....	....	....	....	....
70	5,609,000	....	....	5,263,000	....	4,896,000	4,400,000	3,714,000	....	....	....	....	....
80	6,302,000	....	....	5,696,000	....	5,684,000	5,263,000	4,699,000	....	....	....	....	....
90	7,002,000	....	....	6,723,000	....	6,445,000	6,071,000	5,602,000	3,667,000	....	....	....	....
100	7,694,000	....	....	7,436,000	....	7,165,000	6,791,000	6,445,000	4,862,000	....	....	....	....
125	9,413,000	....	....	....	9,114,000	....	8,740,000	8,421,000	7,280,000	5,419,000	....	....	....
150	11,124,000	....	....	....	10,873,000	....	10,567,000	10,302,000	9,392,000	8,034,000	7,266,000	....	....
175	12,829,000	....	....	....	12,611,000	....	....	12,122,000	11,362,000	10,255,000	8,720,000	6,397,000	....
200	14,540,000	....	....	....	14,350,000	....	....	13,915,000	13,263,000	12,340,000	11,083,000	9,365,000	....
225	16,238,000	....	....	....	16,027,000	....	....	15,688,000	....	14,262,000	13,236,000	11,817,000	7,198,000
250	17,943,000	....	....	....	17,793,000	....	....	17,447,000	....	16,218,000	15,280,000	14,085,000	10,520,000
275	19,647,000	....	....	....	19,505,000	....	....	19,192,000	....	18,078,000	....	16,197,000	13,216,000
300	21,352,000	....	....	....	21,223,000	....	....	20,931,000	....	19,919,000	....	18,221,000	15,634,000
325	23,050,000	....	....	....	22,928,000	....	....	22,663,000	....	21,732,000	....	20,191,000	17,888,000
350	24,755,000	....	....	....	24,639,000	....	....	24,395,000	....	23,525,000	....	22,113,000	20,034,000
375	26,452,000	....	....	....	26,344,000	....	....	26,120,000	....	25,311,000	....	24,001,000	22,099,000
400	28,150,000	....	....	....	28,055,000	....	....	27,777,000	....	27,084,000	....	25,862,000	24,109,000

CAPACITY, IN CUBIC FEET, OF 6″ PIPE LINE 3 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	830,000	......	......	......	......	......	......	......	......	......	......	......	......
20	1,549,000	1,356,000	996,000	......	......	......	......	......	......	......	......	......	......
30	2,241,000	2,070,000	1,854,000	1,566,000	1,107,000	......	......	......	......	......	......	......	......
40	2,834,000	2,712,000	2,551,000	2,347,000	2,092,000	1,749,000	......	......	......	......	......	......	......
50	3,421,000	3,321,000	3,194,000	3,033,000	2,834,000	2,596,000	1,915,000	......	......	......	......	......	......
60	4,002,000	3,913,000	3,808,000	3,670,000	......	3,321,000	2,823,000	2,070,000	......	......	......	......	......
70	4,572,000	......	......	4,290,000	......	3,991,000	3,587,000	3,027,000	......	......	......	......	......
80	5,137,000	......	......	4,887,000	......	4,633,000	4,290,000	3,830,000	......	......	......	......	......
90	5,707,000	......	......	5,480,000	......	5,253,000	4,948,000	4,566,000	2,989,000	......	......	......	......
100	6,271,000	......	......	6,061,000	......	5,840,000	5,535,000	5,253,000	3,963,000	......	......	......	......
125	7,672,000	......	......	......	7,428,000	......	7,124,000	6,864,000	5,934,000	4,417,000	......	......	......
150	9,067,000	......	......	......	8,862,000	......	8,613,000	8,397,000	7,655,000	6,548,000	5,923,000	......	......
175	10,456,000	......	......	......	10,279,000	......	......	9,881,000	9,261,000	8,358,000	7,107,000	5,214,000	......
200	11,851,000	......	......	......	11,696,000	......	......	11,342,000	10,811,000	10,058,000	9,034,000	7,633,000	......
225	13,235,000	......	......	......	13,064,000	......	......	12,787,000	......	11,624,000	10,788,000	9,631,000	5,867,000
250	14,625,000	......	......	......	14,503,000	......	......	14,220,000	......	13,219,000	12,455,000	11,480,000	8,574,000
275	16,014,000	......	......	......	15,898,000	......	......	15,643,000	......	14,735,000	......	13,202,000	10,772,000
300	17,403,000	......	......	......	17,298,000	......	......	17,060,000	......	16,235,000	......	14,852,000	12,742,000
325	18,787,000	......	......	......	18,688,000	......	......	18,472,000	......	17,713,000	......	16,457,000	14,580,000
350	20,177,000	......	......	......	20,083,000	......	......	19,883,000	......	19,175,000	......	18,023,000	16,330,000
375	21,561,000	......	......	......	21,472,000	......	......	21,289,000	......	20,631,000	......	19,562,000	18,012,000
400	22,945,000	......	......	......	22,867,000	......	......	22,640,000	......	22,075,000	......	21,079,000	19,651,000

CAPACITY, IN CUBIC FEET, OF 6″ PIPE LINE 4 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	718,000	…	…	…	…	…	…	…	…	…	…	…	…
20	1,340,000	1,173,000	861,000	…	…	…	…	…	…	…	…	…	…
30	1,939,000	1,790,000	1,603,000	1,355,000	957,000	…	…	…	…	…	…	…	…
40	2,451,000	2,346,000	2,207,000	2,030,000	1,809,000	1,513,000	…	…	…	…	…	…	…
50	2,958,000	2,872,000	2,762,000	2,623,000	2,451,000	2,245,000	1,656,000	…	…	…	…	…	…
60	3,461,000	3,385,000	3,294,000	3,174,000	…	2,872,000	2,441,000	1,790,000	…	…	…	…	…
70	3,954,000	…	…	3,710,000	…	3,452,000	3,102,000	2,619,000	…	…	…	…	…
80	4,443,000	…	…	4,227,000	…	4,007,000	3,710,000	3,313,000	…	…	…	…	…
90	4,936,000	…	…	4,740,000	…	4,543,000	4,280,000	3,950,000	2,585,000	…	…	…	…
100	5,424,000	…	…	5,242,000	…	5,051,000	4,788,000	4,543,000	3,428,000	…	…	…	…
125	6,636,000	…	…	…	6,425,000	…	6,162,000	5,937,000	5,132,000	3,820,000	…	…	…
150	7,842,000	…	…	…	7,665,000	…	7,450,000	7,263,000	6,621,000	5,664,000	5,123,000	…	…
175	9,044,000	…	…	…	8,891,000	…	…	8,546,000	8,010,000	7,229,000	6,147,000	4,510,000	…
200	10,251,000	…	…	…	10,117,000	…	…	9,810,000	9,350,000	8,699,000	7,814,000	6,602,000	…
225	11,448,000	…	…	…	11,299,000	…	…	11,060,000	…	10,054,000	9,331,000	8,331,000	5,075,000
250	12,649,000	…	…	…	12,544,000	…	…	12,300,000	…	11,433,000	10,773,000	9,930,000	7,416,000
275	13,851,000	…	…	…	13,751,000	…	…	13,530,000	…	12,745,000	…	11,419,000	9,317,000
300	15,053,000	…	…	…	14,962,000	…	…	14,756,000	…	14,043,000	…	12,846,000	11,021,000
325	16,250,000	…	…	…	16,164,000	…	…	15,977,000	…	15,321,000	…	14,234,000	12,611,000
350	17,452,000	…	…	…	17,370,000	…	…	17,198,000	…	16,585,000	…	15,589,000	14,124,000
375	18,649,000	…	…	…	18,572,000	…	…	18,414,000	…	17,844,000	…	16,920,000	15,580,000
400	19,846,000	…	…	…	19,779,000	…	…	19,582,000	…	19,094,000	…	18,232,000	16,997,000

CAPACITY, IN CUBIC FEET, OF 6″ PIPE LINE 5 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	641,000	....	....	....	....	....	....	....	....	....	....	....	....
20	1,197,000	1,047,000	769,000	....	....	....	....	....	....	....	....	....	....
30	1,731,000	1,598,000	1,432,000	1,209,000	855,000	....	....	....	....	....	....	....	....
40	2,188,000	2,098,000	1,970,000	1,812,000	1,615,000	1,350,000	....	....	....	....	....	....	....
50	2,641,000	2,565,000	2,466,000	2,342,000	2,188,000	2,004,000	1,479,000	....	....	....	....	....	....
60	3,090,000	3,022,000	2,941,000	2,834,000	2,710,000	2,565,000	2,180,000	1,598,000	....	....	....	....	....
70	3,531,000	....	....	3,313,000	....	3,082,000	2,770,000	2,338,000	....	....	....	....	....
80	3,967,000	....	....	3,774,000	....	3,578,000	3,313,000	2,958,000	....	....	....	....	....
90	4,407,000	....	....	4,232,000	....	4,056,000	3,821,000	3,526,000	2,308,000	....	....	....	....
100	4,843,000	....	....	4,681,000	4,608,000	4,510,000	4,275,000	4,056,000	3,060,000	....	....	....	....
125	5,925,000	....	....	....	5,737,000	....	5,501,000	5,301,000	4,582,000	3,411,000	....	....	....
150	7,002,000	....	....	....	6,844,000	....	6,651,000	6,485,000	5,912,000	5,057,000	4,574,000	....	....
175	8,075,000	....	....	....	7,938,000	....	....	7,630,000	7,152,000	6,455,000	5,489,000	4,027,000	....
200	9,152,000	....	....	....	9,033,000	....	....	8,759,000	8,349,000	7,767,000	6,976,000	5,895,000	....
225	10,221,000	....	....	....	10,089,000	....	....	9,875,000	....	8,977,000	8,331,000	7,438,000	4,531,000
250	11,294,000	....	....	....	11,200,000	....	....	10,982,000	....	10,208,000	9,618,000	8,866,000	6,621,000
275	12,367,000	....	....	....	12,277,000	....	....	12,081,000	....	11,380,000	....	10,195,000	8,319,000
300	13,440,000	....	....	....	13,359,000	....	....	13,175,000	....	12,538,000	....	11,469,000	9,841,000
325	14,509,000	....	....	....	14,432,000	....	....	14,265,000	....	13,680,000	....	12,709,000	11,260,000
350	15,582,000	....	....	....	15,509,000	....	....	15,355,000	....	14,808,000	....	13,919,000	12,611,000
375	16,651,000	....	....	....	16,582,000	....	....	16,441,000	....	15,932,000	....	15,107,000	13,910,000
400	17,719,000	....	....	....	17,660,000	....	....	17,484,000	....	17,048,000	....	16,279,000	15,176,000

CAPACITY, IN CUBIC FEET, OF 6″ PIPE LINE 7 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	542,000	....	....	....	....	....	....	....	....	....	....	....	....
20	1,011,000	885,000	650,000	....	....	....	....	....	....	....	....	....	....
30	1,463,000	1,351,000	1,210,000	1,022,000	722,000	....	....	....	....	....	....	....	....
40	1,850,000	1,770,000	1,665,000	1,532,000	1,366,000	1,141,000	....	....	....	....	....	....	....
50	2,233,000	2,168,000	2,085,000	1,980,000	1,850,000	1,694,000	1,250,000	....	....	....	....	....	....
60	2,612,000	2,554,000	2,486,000	2,395,000	....	2,168,000	1,843,000	1,351,000	....	....	....	....	....
70	2,984,000	....	....	2,800,000	....	2,605,000	2,341,000	1,976,000	....	....	....	....	....
80	3,353,000	....	....	3,190,000	....	3,024,000	2,800,000	2,500,000	....	....	....	....	....
90	3,725,000	....	....	3,577,000	....	3,429,000	3,230,000	2,981,000	1,951,000	....	....	....	....
100	4,094,000	....	....	3,957,000	....	3,812,000	3,613,000	3,429,000	2,587,000	....	....	....	....
125	5,008,000	....	....	....	4,849,000	....	4,509,000	4,481,000	3,873,000	2,883,000	....	....	....
150	5,919,000	....	....	....	5,785,000	....	5,623,000	5,482,000	4,997,000	4,275,000	3,866,000	....	....
175	6,826,000	....	....	....	6,710,000	....	....	6,450,000	6,045,000	5,456,000	4,640,000	3,404,000	....
200	7,737,000	....	....	....	7,635,000	....	....	7,404,000	7,057,000	6,566,000	5,897,000	4,983,000	....
225	8,640,000	....	....	....	8,528,000	....	....	8,347,000	....	7,588,000	7,043,000	6,288,000	3,830,000
250	9,547,000	....	....	....	9,468,000	....	....	9,283,000	....	8,629,000	8,131,000	7,495,000	5,597,000
275	10,454,000	....	....	....	10,378,000	....	....	10,212,000	....	9,619,000	....	8,618,000	7,032,000
300	11,361,000	....	....	....	11,293,000	....	....	11,137,000	....	10,599,000	....	9,695,000	8,318,000
325	12,265,000	....	....	....	12,200,000	....	....	12,059,000	....	11,564,000	....	10,743,000	9,518,000
350	13,172,000	....	....	....	13,110,000	....	....	12,980,000	....	12,518,000	....	11,766,000	10,660,000
375	14,075,000	....	....	....	14,017,000	....	....	13,898,000	....	13,468,000	....	12,771,000	11,759,000
400	14,979,000	....	....	....	14,928,000	....	....	14,780,000	....	14,411,000	....	13,761,000	12,828,000

CAPACITY, IN CUBIC FEET, OF 6″ PIPE LINE 10 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	454,000	...	...	...	...	...	...	...	...	...	...	...	...
20	848,000	742,000	545,000	...	...	...	...	...	...	...	...	...	...
30	1,227,000	1,133,000	1,015,000	857,000	606,000	...	...	...	...	...	...	...	...
40	1,551,000	1,484,000	1,397,000	1,284,000	1,145,000	957,000	...	...	...	...	...	...	...
50	1,872,000	1,818,000	1,748,000	1,660,000	1,551,000	1,421,000	1,048,000	...	...	...	...	...	...
60	2,191,000	2,142,000	2,084,000	2,009,000	1,921,000	1,818,000	1,545,000	1,133,000	...	...	...	...	...
70	2,503,000	...	...	2,348,000	...	2,184,000	1,963,000	1,657,000	...	...	...	...	...
80	2,812,000	...	...	2,675,000	...	2,536,000	2,348,000	2,097,000	...	...	...	...	...
90	3,124,000	...	...	3,000,000	...	2,875,000	2,709,000	2,500,000	1,636,000	...	...	...	...
100	3,427,000	...	...	3,318,000	3,266,000	3,197,000	3,030,000	2,875,000	2,169,000	...	...	...	...
125	4,200,000	...	...	...	4,066,000	...	3,900,000	3,751,000	3,248,000	2,418,000	...	...	...
150	4,963,000	...	...	...	4,851,000	...	4,715,000	4,597,000	4,191,000	3,585,000	3,242,000	...	...
175	5,724,000	...	...	...	5,627,000	...	...	5,409,000	5,070,000	4,576,000	3,891,000	2,854,000	...
200	6,488,000	...	...	...	6,403,000	...	...	6,209,000	5,918,000	5,506,000	4,945,000	4,179,000	...
225	7,245,000	...	...	...	7,151,000	...	...	7,000,000	...	6,364,000	5,906,000	5,273,000	3,212,000
250	8,006,000	...	...	...	7,939,000	...	...	7,785,000	...	7,236,000	6,818,000	6,285,000	4,694,000
275	8,767,000	...	...	...	8,703,000	...	...	8,564,000	...	8,067,000	...	7,227,000	5,897,000
300	9,527,000	...	...	...	9,470,000	...	...	9,340,000	...	8,888,000	...	8,130,000	6,976,000
325	10,285,000	...	...	...	10,230,000	...	...	10,112,000	...	9,697,000	...	9,009,000	7,982,000
350	11,046,000	...	...	...	10,994,000	...	...	10,885,000	...	10,497,000	...	9,867,000	8,939,000
375	11,803,000	...	...	...	11,755,000	...	...	11,655,000	...	11,294,000	...	10,709,000	9,861,000
400	12,561,000	...	...	...	12,518,000	...	...	12,394,000	...	12,085,000	...	11,540,000	10,758,000

CAPACITY, IN CUBIC FEET, OF 6″ PIPE LINE 15 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	371,000	....	....	....	....	....	....	....	....	....	....	....	....
20	692,000	606,000	445,000	....	....	....	....	....	....	....	....	....	....
30	1,002,000	925,000	829,000	700,000	494,000	....	....	....	....	....	....	....	....
40	1,267,000	1,212,000	1,140,000	1,049,000	935,000	782,000	....	....	....	....	....	....	....
50	1,529,000	1,484,000	1,427,000	1,356,000	1,267,000	1,160,000	856,000	....	....	....	....	....	....
60	1,789,000	1,749,000	1,702,000	1,640,000	1,568,000	1,484,000	1,262,000	925,000	....	....	....	....	....
70	2,044,000	....	....	1,917,000	....	1,784,000	1,603,000	1,353,000	....	....	....	....	....
80	2,296,000	....	....	2,185,000	....	2,071,000	1,917,000	1,712,000	....	....	....	....	....
90	2,551,000	....	....	2,449,000	....	2,348,000	2,212,000	2,041,000	1,336,000	....	....	....	....
100	2,803,000	....	....	2,709,000	2,667,000	2,610,000	2,474,000	2,348,000	1,771,000	....	....	....	....
125	3,429,000	....	....	....	3,321,000	....	3,184,000	3,068,000	2,652,000	1,974,000	....	....	....
150	4,053,000	....	....	....	3,961,000	....	3,850,000	3,754,000	3,422,000	2,927,000	2,647,000	....	....
175	4,674,000	....	....	....	4,595,000	....	....	4,417,000	4,140,000	3,736,000	3,177,000	2,331,000	....
200	5,298,000	....	....	....	5,229,000	....	....	5,070,000	4,833,000	4,496,000	4,038,000	3,412,000	....
225	5,917,000	....	....	....	5,840,000	....	....	5,716,000	....	5,196,000	4,823,000	4,305,000	2,623,000
250	6,538,000	....	....	....	6,483,000	....	....	6,357,000	....	5,909,000	5,568,000	5,132,000	3,833,000
275	7,159,000	....	....	....	7,107,000	....	....	6,993,000	....	6,587,000	....	5,902,000	4,815,000
300	7,780,000	....	....	....	7,733,000	....	....	7,627,000	....	7,258,000	....	6,639,000	5,696,000
325	8,399,000	....	....	....	8,354,000	....	....	8,258,000	....	7,919,000	....	7,357,000	6,518,000
350	9,020,000	....	....	....	8,978,000	....	....	8,889,000	....	8,572,000	....	8,057,000	7,300,000
375	9,638,000	....	....	....	9,599,000	....	....	9,517,000	....	9,223,000	....	8,745,000	8,052,000
400	10,257,000	....	....	....	10,222,000	....	....	10,121,000	....	9,869,000	....	9,423,000	8,785,000

CAPACITY, IN CUBIC FEET, OF 6″ PIPE LINE 20 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	321,000	....	....	....	....	....	....	....	....	....	....	....	....
20	599,000	524,000	385,000	....	....	....	....	....	....	....	....	....	....
30	867,000	801,000	717,000	606,000	428,000	....	....	....	....	....	....	....	....
40	1,096,000	1,049,000	987,000	908,000	809,000	676,000	....	....	....	....	....	....	....
50	1,323,000	1,285,000	1,236,000	1,173,000	1,096,000	1,004,000	741,000	....	....	....	....	....	....
60	1,548,000	1,514,000	1,473,000	1,420,000	1,358,000	1,285,000	1,092,000	801,000	....	....	....	....	....
70	1,769,000	....	....	1,660,000	....	1,544,000	1,388,000	1,171,000	....	....	....	....	....
80	1,987,000	....	....	1,891,000	....	1,793,000	1,660,000	1,482,000	....	....	....	....	....
90	2,208,000	....	....	2,120,000	....	2,032,000	1,915,000	1,767,000	1,156,000	....	....	....	....
100	2,427,000	....	....	2,345,000	2,309,000	2,260,000	2,142,000	2,032,000	1,533,000	....	....	....	....
125	2,969,000	....	....	....	2,874,000	....	2,757,000	2,656,000	2,296,000	1,709,000	....	....	....
150	3,508,000	....	....	....	3,429,000	....	3,333,000	3,249,000	2,962,000	2,534,000	2,292,000	....	....
175	4,046,000	....	....	....	3,978,000	....	....	3,823,000	3,583,000	3,234,000	2,750,000	2,017,000	....
200	4,586,000	....	....	....	4,526,000	....	....	4,389,000	4,183,000	3,892,000	3,496,000	2,954,000	....
225	5,122,000	....	....	....	5,055,000	....	....	4,948,000	....	4,498,000	4,175,000	3,727,000	2,270,000
250	5,659,000	....	....	....	5,612,000	....	....	5,503,000	....	5,115,000	4,819,000	4,442,000	3,318,000
275	6,197,000	....	....	....	6,152,000	....	....	6,053,000	....	5,702,000	....	5,109,000	4,168,000
300	6,735,000	....	....	....	6,694,000	....	....	6,602,000	....	6,283,000	....	5,747,000	4,931,000
325	7,270,000	....	....	....	7,232,000	....	....	7,148,000	....	6,855,000	....	6,368,000	5,642,000
350	7,808,000	....	....	....	7,771,000	....	....	7,694,000	....	7,420,000	....	6,975,000	6,319,000
375	8,343,000	....	....	....	8,309,000	....	....	8,238,000	....	7,983,000	....	7,570,000	6,970,000
400	8,879,000	....	....	....	8,849,000	....	....	8,761,000	....	8,543,000	....	8,157,000	7,604,000

CAPACITY, IN CUBIC FEET, OF 6" PIPE LINE 30 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	262,000	....	....	....	....	....	....	....	....	....	....	....	....
20	489,000	428,000	314,000	....	....	....	....	....	....	....	....	....	....
30	707,000	653,000	585,000	494,000	349,000	....	....	....	....	....	....	....	....
40	894,000	856,000	805,000	740,000	660,000	552,000	....	....	....	....	....	....	....
50	1,079,000	1,048,000	1,008,000	957,000	894,000	819,000	604,000	....	....	....	....	....	....
60	1,263,000	1,235,000	1,201,000	1,158,000	1,107,000	1,048,000	890,000	653,000	....	....	....	....	....
70	1,443,000	....	....	1,353,000	....	1,259,000	1,132,000	955,000	....	....	....	....	....
80	1,621,000	....	....	1,542,000	....	1,462,000	1,353,000	1,208,000	....	....	....	....	....
90	1,801,000	....	....	1,729,000	....	1,657,000	1,561,000	1,441,000	943,000	....	....	....	....
100	1,979,000	....	....	1,912,000	1,883,000	1,843,000	1,747,000	1,657,000	1,250,000	....	....	....	....
125	2,421,000	....	....	....	2,344,000	....	2,248,000	2,166,000	1,872,000	1,394,000	....	....	....
150	2,861,000	....	....	....	2,796,000	....	2,718,000	2,650,000	2,416,000	2,066,000	1,869,000	....	....
175	3,300,000	....	....	....	3,244,000	....	....	3,118,000	2,922,000	2,637,000	2,243,000	1,645,000	....
200	3,740,000	....	....	....	3,691,000	....	....	3,579,000	3,411,000	3,174,000	2,851,000	2,409,000	....
225	4,177,000	....	....	....	4,122,000	....	....	4,035,000	....	3,668,000	3,404,000	3,039,000	1,851,000
250	4,615,000	....	....	....	4,577,000	....	....	4,488,000	....	4,171,000	3,930,000	3,623,000	2,706,000
275	5,054,000	....	....	....	5,017,000	....	....	4,937,000	....	4,650,000	....	4,166,000	3,399,000
300	5,492,000	....	....	....	5,459,000	....	....	5,384,000	....	5,123,000	....	4,687,000	4,021,000
325	5,929,000	....	....	....	5,897,000	....	....	5,829,000	....	5,590,000	....	5,193,000	4,601,000
350	6,367,000	....	....	....	6,338,000	....	....	6,275,000	....	6,051,000	....	5,688,000	5,153,000
375	6,804,000	....	....	....	6,776,000	....	....	6,718,000	....	6,511,000	....	6,173,000	5,684,000
400	7,241,000	....	....	....	7,216,000	....	....	7,145,000	....	6,967,000	....	6,652,000	6,201,000

CAPACITY, IN CUBIC FEET, OF 6″ PIPE LINE 40 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	227,000	....	....	....	....	....	....	....	....	....	....	....	....
20	424,000	371,000	272,000	....	....	....	....	....	....	....	....	....	....
30	613,000	566,000	507,000	428,000	303,000	....	....	....	....	....	....	....	....
40	775,000	742,000	698,000	642,000	572,000	478,000	....	....	....	....	....	....	....
50	936,000	909,000	874,000	830,000	775,000	710,000	524,000	....	....	....	....	....	....
60	1,095,000	1,071.000	1,042,000	1,004,000	....	909,000	772,000	566,000	....	....	....	....	....
70	1,251,000	....	....	1,174,000	....	1,092,000	981,000	828,000	....	....	....	....	....
80	1,406,000	....	....	1,337,000	....	1,268,000	1,174,000	1,048,000	....	....	....	....	....
90	1,562,000	....	....	1,500,000	....	1,437,000	1,354,000	1,250,000	818,000	....	....	....	....
100	1,716,000	....	....	1,659,000	....	1,598,000	1,515,000	1,437,000	1,084,000	....	....	....	....
125	2,100,000	....	....	....	2,033,000	....	1,950,000	1,878,000	1,624,000	1,209,000	....	....	....
150	2,481,000	....	....	....	2,425,000	....	2,357,000	2,298,000	2,095,000	1,792,000	1,621,000	....	....
175	2,862,000	....	....	....	2,813,000	....	....	2,704,000	2,534,000	2,287,000	1,945,000	1,427,000	....
200	3,244,000	....	....	....	3,201,000	....	....	3,104,000	2,959,000	2,753,000	2,472,000	2,089,000	....
225	3,622,000	....	....	....	3,575,000	....	....	3,506,000	....	3,181,000	2,953,000	2,636,000	1,606,000
250	4,003,000	....	....	....	3,969,000	....	....	3,892,000	....	3,618,000	3,409,000	3,142,000	2,347,000
275	4,383,000	....	....	....	4,351,000	....	....	4,281,000	....	4,033,000	....	3,613,000	2,948,000
300	4,763,000	....	....	....	4,735,000	....	....	4,669,000	....	4,444,000	....	4,065,000	3,487,000
325	5,142,000	....	....	....	5,115,000	....	....	5,056,000	....	4,848,000	....	4,504,000	3,991,000
350	5,522,000	....	....	....	5,497,000	....	....	5,442,000	....	5,248,000	....	4,933,000	4,469,000
375	5,901,000	....	....	....	5,877,000	....	....	5,827,000	....	5,647,000	....	5,354,000	4,930,000
400	6,280,000	....	....	....	6,259,000	....	....	6,197,000	....	6,042,000	....	5,769,000	5,378,000

CAPACITY, IN CUBIC FEET, OF 6″ PIPE LINE 50 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	203,000	...	...	...	...	...	...	...	...	...	...	...	...
20	379,000	331,000	243,000	...	...	...	...	...	...	...	...	...	...
30	548,000	506,000	453,000	383,000	270,000	...	...	...	...	...	...	...	...
40	693,000	663,000	624,000	574,000	512,000	428,000	...	...	...	...	...	...	...
50	837,000	812,000	781,000	742,000	693,000	635,000	468,000	...	...	...	...	...	...
60	979,000	957,000	932,000	898,000	858,000	812,000	690,000	506,000	...	...	...	...	...
70	1,118,000	...	...	1,049,000	...	976,000	877,000	741,000	...	...	...	...	...
80	1,257,000	...	...	1,196,000	...	1,133,000	1,049,000	937,000	...	...	...	...	...
90	1,396,000	...	...	1,341,000	...	1,285,000	1,211,000	1,117,000	731,000	...	...	...	...
100	1,534,000	...	...	1,483,000	1,460,000	1,429,000	1,354,000	1,285,000	969,000	...	...	...	...
125	1,877,000	...	...	...	1,818,000	...	1,743,000	1,679,000	1,452,000	1,083,000	...	...	...
150	2,218,000	...	...	...	2,168,000	...	2,107,000	2,055,000	1,873,000	1,602,000	1,449,000	...	...
175	2,559,000	...	...	...	2,515,000	...	...	2,418,000	2,266,000	2,045,000	1,739,000	1,276,000	...
200	2,900,000	...	...	...	2,862,000	...	...	2,775,000	2,645,000	2,461,000	2,210,000	1,868,000	...
225	3,239,000	...	...	...	3,197,000	...	...	3,129,000	...	2,844,000	2,640,000	2,357,000	1,435,000
250	3,579,000	...	...	...	3,549,000	...	...	3,480,000	...	3,235,000	3,048,000	2,809,000	2,098,000
275	3,919,000	...	...	...	3,890,000	...	...	3,828,000	...	3,606,000	...	3,230,000	2,636,000
300	4,259,000	...	...	...	4,233,000	...	...	4,175,000	...	3,973,000	...	3,634,000	3,118,000
325	4,597,000	...	...	...	4,573,000	...	...	4,520,000	...	4,335,000	...	4,027,000	3,568,000
350	4,937,000	...	...	...	4,914,000	...	...	4,866,000	...	4,692,000	...	4,410,000	3,996,000
375	5,276,000	...	...	...	5,254,000	...	...	5,210,000	...	5,048,000	...	4,787,000	4,408,000
400	5,615,000	...	...	...	5,596,000	...	...	5,540,000	...	5,402,000	...	5,058,000	4,809,000

CAPACITY, IN CUBIC FEET, OF 6″ PIPE LINE 70 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	171,000	....	....	....	....	....	....	....	....	....	....	....	....
20	320,000	280,000	205,000	....	....	....	....	....	....	....	....	....	....
30	463,000	427,000	383,000	323,000	228,000	....	....	....	....	....	....	....	....
40	585,000	560,000	527,000	484,000	432,000	361,000	....	....	....	....	....	....	....
50	706,000	686,000	659,000	626,000	585,000	536,000	395,000	....	....	....	....	....	....
60	826,000	808,000	786,000	758,000	....	686,000	583,000	427,000	....	....	....	....	....
70	944,000	....	....	886,000	....	824,000	741,000	625,000	....	....	....	....	....
80	1,061,000	....	....	1,009,000	....	957,000	886,000	791,000	....	....	....	....	....
90	1,179,000	....	....	1,132,000	....	1,085,000	1,022,000	943,000	617,000	....	....	....	....
100	1,295,000	....	....	1,252,000	....	1,206,000	1,143,000	1,085,000	818,000	....	....	....	....
125	1,585,000	....	....	....	1,534,000	....	1,472,000	1,418,000	1,226,000	912,000	....	....	....
150	1,873,000	....	....	....	1,831,000	....	1,779,000	1,735,000	1,581,000	1,353,000	1,223,000	....	....
175	2,160,000	....	....	....	2,124,000	....	....	2,041,000	1,913,000	1,727,000	1,468,000	1,077,000	....
200	2,448,000	....	....	....	2,416,000	....	....	2,343,000	2,233,000	2,078,000	1,866,000	1,577,000	....
225	2,734,000	....	....	....	2,699,000	....	....	2,642,000	....	2,401,000	2,229,000	1,990,000	1,212,000
250	3,021,000	....	....	....	2,996,000	....	....	2,938,000	....	2,731,000	2,573,000	2,372,000	1,771,000
275	3,309,000	....	....	....	3,284,000	....	....	3,232,000	....	3,044,000	....	2,727,000	2,225,000
300	3,596,000	....	....	....	3,574,000	....	....	3,525,000	....	3,354,000	....	3,068,000	2,633,000
325	3,882,000	....	....	....	3,861,000	....	....	3,816,000	....	3,660,000	....	3,400,000	3,012,000
350	4,169,000	....	....	....	4,149,000	....	....	4,108,000	....	3,962,000	....	3,724,000	3,374,000
375	4,455,000	....	....	....	4,436,000	....	....	4,399,000	....	4,262,000	....	4,042,000	3,721,000
400	4,741,000	....	....	....	4,725,000	....	....	4,678,000	....	4,561,000	....	4,355,000	4,060,000

CAPACITY, IN CUBIC FEET, OF 6″ PIPE LINE 100 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	143,000	....	....	....	....	....	....	....	....	....	....	....	....
20	268,000	234,000	172,000	....	....	....	....	....	....	....	....	....	....
30	387,000	358,000	320,000	271,000	191,000	....	....	....	....	....	....	....	....
40	490,000	469,000	441,000	406,000	361,000	302,000	....	....	....	....	....	....	....
50	591,000	574,000	552,000	524,000	490,000	449,000	331,000	....	....	....	....	....	....
60	692,000	677,000	658,000	634,000	607,000	574,000	488,000	358,000	....	....	....	....	....
70	790,000	....	....	742,000	....	690,000	620,000	523,000	....	....	....	....	....
80	888,000	....	....	845,000	....	801,000	742,000	662,000	....	....	....	....	....
90	987,000	....	....	948,000	....	908,000	856,000	790,000	517,000	....	....	....	....
100	1,084,000	....	....	1,048,000	1,032,000	1,010,000	957,000	908,000	685,000	....	....	....	....
125	1,327,000	....	....	....	1,285,000	....	1,237,000	1,187,000	1,026,000	764,000	....	....	....
150	1,568,000	....	....	....	1,533,000	....	1,490,000	1,452,000	1,324,000	1,132,000	1,024,000	....	....
175	1,808,000	....	....	....	1,778,000	....	....	1,709,000	1,602,000	1,445,000	1,229,000	902,000	....
200	2,050,000	....	....	....	2,023,000	....	....	1,962,000	1,870,000	1,739,000	1,562,000	1,320,000	....
225	2,289,000	....	....	....	2,259,000	....	....	2,212,000	....	2,010,000	1,866,000	1,666,000	1,015,000
250	2,529,000	....	....	....	2,508,000	....	....	2,460,000	....	2,286,000	2,154,000	1,986,000	1,483,000
275	2,770,000	....	....	....	2,750,000	....	....	2,706,000	....	2,549,000	....	2,283,000	1,863,000
300	3,010,000	....	....	....	2,992,000	....	....	2,951,000	....	2,808,000	....	2,569,000	2,204,000
325	3,250,000	....	....	....	3,232,000	....	....	3,195,000	....	3,064,000	....	2,846,000	2,522,000
350	3,490,000	....	....	....	3,474,000	....	....	3,439,000	....	3,317,000	....	3,117,000	2,824,000
375	3,729,000	....	....	....	3,714,000	....	....	3,682,000	....	3,568,000	....	3,384,000	3,116,000
400	3,969,000	....	....	....	3,955,000	....	....	3,916,000	....	3,818,000	....	3,646,000	3,399,000

CAPACITY, IN CUBIC FEET, OF 8″ PIPE LINE 1 MILE LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	2,993,000												
20	5,588,000	4,889,000	3,592,000										
30	8,083,000	7,464,000	6,686,000	5,648,000	3,991,000								
40	10,218,000	9,779,000	9,200,000	8,462,000	7,544,000	6,306,000							
50	12,334,000	11,975,000	11,515,000	10,937,000	10,218,000	9,360,000	6,905,000						
60	14,429,000	14,110,000	13,731,000	13,232,000		11,975,000	10,178,000	7,464,000					
70	16,485,000			15,467,000		14,390,000	12,933,000	10,917,000					
80	18,521,000			17,623,000		16,705,000	15,467,000	13,811,000					
90	20,577,000			19,758,000		18,940,000	17,842,000	16,465,000	10,777,000				
100	22,612,000			21,854,000		21,056,000	19,958,000	18,940,000	14,290,000				
125	27,662,000				26,784,000		25,686,000	24,748,000	21,395,000	15,926,000			
150	32,691,000				31,953,000		31,055,000	30,276,000	27,602,000	23,610,000	21,355,000		
175	37,701,000				37,062,000			35,625,000	33,390,000	30,137,000	25,626,000	18,809,000	
200	42,730,000				42,172,000			40,894,000	38,978,000	36,264,000	32,572,000	27,522,000	
225	47,720,000				47,101,000			46,103,000		41,912,000	38,898,000	34,727,000	21,155,000
250	52,730,000				52,291,000			51,273,000		47,660,000	44,906,000	41,393,000	30,915,000
275	57,739,000				57,320,000			56,402,000		53,129,000		47,600,000	38,839,000
300	62,749,000				62,370,000			61,511,000		58,537,000		53,548,000	45,944,000
325	67,738,000				67,379,000			66,601,000		63,866,000		59,336,000	52,570,000
350	72,748,000				72,409,000			71,690,000		69,135,000		64,984,000	58,877,000
375	77,737,000				77,418,000			76,760,000		74,384,000		70,532,000	64,944,000
400	82,727,000				82,448,000			81,629,000		79,594,000		76,001,000	70,852,000

CAPACITY, IN CUBIC FEET, OF 8″ PIPE LINE 2 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	2,123,000												
20	3,963,000	3,467,000	2,547,000										
30	5,732,000	5,293,000	4,741,000	4,005,000	2,831,000								
40	7,247,000	6,935,000	6,525,000	6,001,000	5,350,000	4,472,000							
50	8,747,000	8,493,000	8,167,000	7,756,000	7,247,000	6,638,000	4,897,000						
60	10,234,000	10,007,000	9,738,000	9,381,000		8,493,000	7,219,000	5,293,000					
70	11,692,000			10,970,000		10,205,000	9,172,000	7,742,000					
80	13,135,000			12,498,000		11,847,000	10,970,000	9,795,000					
90	14,593,000			14,013,000		13,433,000	12,654,000	11,677,000	7,643,000				
100	16,037,000			15,499,000		14,933,000	14,155,000	13,433,000	10,134,000				
125	19,618,000				18,996,000		18,217,000	17,552,000	15,174,000	11,295,000			
150	23,185,000				22,662,000		22,025,000	21,473,000	19,576,000	16,745,000	15,145,000		
175	26,738,000				26,285,000			25,266,000	23,681,000	21,374,000	18,175,000	13,334,000	
200	30,305,000				29,909,000			29,003,000	27,644,000	25,719,000	23,100,000	19,519,000	
225	33,844,000				33,405,000			32,698,000		29,725,000	27,588,000	24,629,000	15,004,000
250	37,397,000				37,086,000			36,364,000		33,802,000	31,848,000	29,357,000	21,926,000
275	40,950,000				40,653,000			40,002,000		37,680,000		33,759,000	27,545,000
300	44,503,000				44,234,000			43,625,000		41,516,000		37,977,000	32,584,000
325	48,042,000				47,787,000			47,235,000		45,296,000		42,082,000	37,284,000
350	51,594,000				51,354,000			50,844,000		49,032,000		46,088,000	41,757,000
375	55,133,000				54,907,000			54,440,000		52,755,000		50,023,000	46,060,000
400	58,672,000				58,474,000			57,893,000		56,450,000		53,902,000	50,250,000

CAPACITY, IN CUBIC FEET, OF 8″ PIPE LINE 3 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,730,000												
20	3,230,000	2,826,000	2,076,000										
30	4,672,000	4,314,000	3,865,000	3,265,000	2,307,000								
40	5,907,000	5,653,000	5,318,000	4,891,000	4,361,000	3,645,000							
50	7,130,000	6,922,000	6,657,000	6,322,000	5,907,000	5,411,000	3,991,000						
60	8,341,000	8,156,000	7,937,000	7,649,000		6,922,000	5,884,000	4,314,000					
70	9,529,000			8,941,000		8,318,000	7,476,000	6,310,000					
80	10,706,000			10,187,000		9,656,000	8,941,000	7,983,000					
90	11,895,000			11,422,000		10,948,000	10,314,000	9,518,000	6,230,000				
100	13,071,000			12,633,000		12,171,000	11,537,000	10,948,000	8,260,000				
125	15,990,000				15,483,000		14,848,000	14,306,000		9,206,000			
150	18,898,000				18,471,000		17,952,000	17,502,000	15,956,000	13,648,000	12,345,000		
175	21,794,000				21,424,000			20,594,000	19,302,000	17,421,000	14,814,000	10,868,000	
200	24,701,000				24,378,000			23,640,000	22,532,000	20,963,000	18,829,000	15,910,000	
225	27,585,000				27,228,000			26,651,000		24,228,000	22,486,000	20,075,000	12,229,000
250	30,481,000				30,227,000			29,639,000		27,551,000	25,959,000	23,928,000	17,871,000
275	33,377,000				33,135,000			32,604,000		30,712,000		27,516,000	22,451,000
300	36,273,000				36,054,000			35,558,000		33,839,000		30,954,000	26,559,000
325	39,157,000				38,950,000			38,500,000		36,919,000		34,300,000	30,389,000
350	42,053,000				41,857,000			41,442,000		39,965,000		37,565,000	34,035,000
375	44,938,000				44,753,000			44,372,000		42,999,000		40,773,000	37,542,000
400	47,822,000				47,660,000			47,187,000		46,011,000		43,934,000	40,957,000

CAPACITY, IN CUBIC FEET, OF 8″ PIPE LINE 4 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,496,000	....	....	....	....	....	....	....	....	....	....	....	....
20	2,794,000	2,444,000	1,796,000	....	....	....	....	....	....	....	....	....	....
30	4,041,000	3,732,000	3,343,000	2,824,000	1,995,000	....	....	....	....	....	....	....	....
40	5,109,000	4,889,000	4,600,000	4,231,000	3,772,000	3,153,000	....	....	....	....	....	....	....
50	6,167,000	5,987,000	5,757,000	5,468,000	5,109,000	4,680,000	3,452,000	....	....	....	....	....	....
60	7,214,000	7,055,000	6,865,000	6,616,000	....	5,987,000	5,089,000	3,732,000	....	....	....	....	....
70	8,242,000	....	....	7,733,000	....	7,195,000	6,466,000	5,458,000	....	....	....	....	....
80	9,260,000	....	....	8,811,000	....	8,352,000	7,733,000	6,905,000	....	....	....	....	....
90	10,288,000	....	....	9,879,000	....	9,470,000	8,921,000	8,232,000	5,388,000	....	....	....	....
100	11,306,000	....	....	10,927,000	....	10,528,000	9,979,000	9,470,000	7,145,000	....	....	....	....
125	13,831,000	....	....	....	13,392,000	....	12,843,000	12,374,000	10,697,000	7,963,000	....	....	....
150	16,345,000	....	....	....	15,976,000	....	15,527,000	15,138,000	13,801,000	11,805,000	10,677,000	....	....
175	18,850,000	....	....	....	18,531,000	....	....	17,812,000	16,695,000	15,068,000	12,813,000	9,400,000	....
200	21,365,000	....	....	....	21,086,000	....	....	20,447,000	19,489,000	18,132,000	16,286,000	13,761,000	....
225	23,860,000	....	....	....	23,550,000	....	....	23,051,000	....	20,956,000	19,449,000	17,363,000	10,577,000
250	26,365,000	....	....	....	26,145,000	....	....	25,636,000	....	23,830,000	22,453,000	20,696,000	15,457,000
275	28,869,000	....	....	....	28,660,000	....	....	28,201,000	....	26,564,000	....	23,800,000	19,419,000
300	31,374,000	....	....	....	31,185,000	....	....	30,755,000	....	29,268,000	....	26,774,000	22,972,000
325	33,869,000	....	....	....	33,689,000	....	....	33,300,000	....	31,933,000	....	29,668,000	26,275,000
350	36,374,000	....	....	....	36,204,000	....	....	35,845,000	....	34,567,000	....	32,492,000	29,438,000
375	38,868,000	....	....	....	38,709,000	....	....	38,380,000	....	37,192,000	....	35,266,000	32,472,000
400	41,363,000	....	....	....	41,224,000	....	....	40,814,000	....	39,797,000	....	38,000,000	35,426,000

CAPACITY, IN CUBIC FEET, OF 8″ PIPE LINE 5 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,336,000	......	......	......	......	......	......	......	......	......	......	......	......
20	2,494,000	2,182,000	1,603,000	......	......	......	......	......	......	......	......	......	......
30	3,608,000	3,332,000	2,984,000	2,521,000	1,782,000	......	......	......	......	......	......	......	......
40	4,561,000	4,365,000	4,107,000	3,777,000	3,367,000	2,815,000	......	......	......	......	......	......	......
50	5,506,000	5,346,000	5,141,000	4,882,000	4,561,000	4,178,000	3,082,000	......	......	......	......	......	......
60	6,441,000	6,299,000	6,130,000	5,907,000	5,648,000	5,346,000	4,544,000	3,332,000	......	......	......	......	......
70	7,359,000	......	......	6,905,000	......	6,424,000	5,773,000	4,873,000	......	......	......	......	......
80	8,268,000	......	......	7,867,000	......	7,457,000	6,905,000	6,165,000	......	......	......	......	......
90	9,186,000	......	......	8,820,000	......	8,455,000	7,965,000	7,350,000	4,811,000	......	......	......	......
100	10,095,000	......	......	9,756,000	......	9,400,000	8,910,000	8,455,000	6,379,000	......	......	......	......
125	12,349,000	......	......	......	11,957,000	......	11,467,000	11,048,000	9,551,000	7,110,000	......	......	......
150	14,594,000	......	......	......	14,264,000	......	13,863,000	13,516,000	12,322,000	10,540,000	9,533,000	......	......
175	16,830,000	......	......	......	16,545,000	......	......	15,904,000	14,906,000	13,454,000	11,440,000	8,393,000	......
200	19,076,000	......	......	......	18,826,000	......	......	18,256,000	17,401,000	16,189,000	14,541,000	12,286,000	......
225	21,303,000	......	......	......	21,027,000	......	......	20,582,000	......	18,711,000	17,365,000	15,503,000	9,444,000
250	23,540,000	......	......	......	23,344,000	......	......	22,889,000	......	21,277,000	20,047,000	18,479,000	13,801,000
275	25,776,000	......	......	......	25,589,000	......	......	25,179,000	......	23,718,000	......	21,250,000	17,338,000
300	28,013,000	......	......	......	27,843,000	......	......	27,460,000	......	26,133,000	......	23,905,000	20,510,000
325	30,240,000	......	......	......	30,080,000	......	......	29,732,000	......	28,512,000	......	26,489,000	23,468,000
350	32,476,000	......	......	......	32,325,000	......	......	32,004,000	......	30,864,000	......	29,010,000	26,284,000
375	34,704,000	......	......	......	34,561,000	......	......	34,267,000	......	33,207,000	......	31,487,000	28,993,000
400	36,931,000	......	......	......	36,807,000	......	......	36,441,000	......	35,533,000	......	33,929,000	31,630,000

CAPACITY, IN CUBIC FEET, OF 8″ PIPE LINE 7 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,129,000	....	....	....	....	....	....	....	....	....	....	....	....
20	2 108,000	1,845,000	1,355,000	....	....	....	....	....	....	....	....	....	....
30	3,050,000	2,816,000	2,523,000	2,131,000	1,506,000	....	....	....	....	....	....	....	....
40	3,856,000	3,690,000	3,472,000	3,193,000	2,847,000	2,380,000	....	....	....	....	....	....	....
50	4,654,000	4,519,000	4,345,000	4,127,000	3,856,000	3,532,000	2,606,000	....	....	....	....	....	....
60	5,445,000	5,325,000	5,181,000	4,993,000	....	4,519,000	3,841,000	2,816,000	....	....	....	....	....
70	6,221,000	....	....	5,837,000	....	5,430,000	4,880,000	4,119,000	....	....	....	....	....
80	6,989,000	....	....	6,650,000	....	6,304,000	5,837,000	5,212,000	....	....	....	....	....
90	7,765,000	....	....	7,456,000	....	7,147,000	6,733,000	6,213,000	4,067,000	....	....	....	....
100	8,533,000	....	....	8,247,000	....	7,946,000	7,531,000	7,147,000	5,392,000	....	....	....	....
125	10,439,000	....	....	....	10,107,000	....	9,693,000	9,339,000	8,074,000	6,010,000	....	....	....
150	12,337,000	....	....	....	12,058,000	....	11,719,000	11,425,000	10,416,000	8,910,000	8,059,000	....	....
175	14,227,000	....	....	....	13,986,000	....	....	13,444,000	12,600,000	11,373,000	9,670,000	7,095,000	....
200	16,125,000	....	....	....	15,914,000	....	....	15,432,000	14,709,000	13,685,000	12,292,000	10,386,000	....
225	18,008,000	....	....	....	17,775,000	....	....	17,398,000	....	15,816,000	14,679,000	13,105,000	7,983,000
250	19,899,000	....	....	....	19,733,000	....	....	19,349,000	....	17,986,000	16,946,000	15,621,000	11,666,000
275	21,789,000	....	....	....	21,631,000	....	....	21,285,000	....	20,049,000	....	17,963,000	14,657,000
300	23,680,000	....	....	....	23,537,000	....	....	23,213,000	....	22,091,000	....	20,208,000	17,338,000
325	25,563,000	....	....	....	25,426,000	....	....	25,133,000	....	24,102,000	....	22,392,000	19,839,000
350	27,453,000	....	....	....	27,325,000	....	....	27,054,000	....	26,090,000	....	24,523,000	22,219,000
375	29,336,000	....	....	....	29,216,000	....	....	28,967,000	....	28,071,000	....	26,617,000	24,508,000
400	31,219,000	....	....	....	31,114,000	....	....	30,805,000	....	30,037,000	....	28,681,000	26,738,000

CAPACITY, IN CUBIC FEET, OF 8″ PIPE LINE 10 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	947,000	...	...	...	...	...	...	...	...	...	...	...	...
20	1,768,000	1,547,000	1,136,000	...	...	...	...	...	...	...	...	...	...
30	2,558,000	2,362,000	2,115,000	1,787,000	1,263,000	...	...	...	...	...	...	...	...
40	3,233,000	3,094,000	2,911,000	2,678,000	2,387,000	1,995,000	...	...	...	...	...	...	...
50	3,903,000	3,789,000	3,644,000	3,461,000	3,233,000	2,962,000	2,185,000	...	...	...	...	...	...
60	4,566,000	4,465,000	4,345,000	4,187,000	...	3,789,000	3,221,000	2,362,000	...	...	...	...	...
70	5,217,000	...	...	4,895,000	...	4,553,000	4,092,000	3,454,000	...	...	...	...	...
80	5,861,000	...	...	5,577,000	...	5,286,000	4,895,000	4,370,000	...	...	...	...	...
90	6,512,000	...	...	6,253,000	...	5,994,000	5,646,000	5,210,000	3,410,000	...	...	...	...
100	7,156,000	...	...	6,916,000	...	6,663,000	6,316,000	5,994,000	4,522,000	...	...	...	...
125	8,754,000	...	...	...	8,476,000	...	8,128,000	7,832,000	6,770,000	5,040,000	...	...	...
150	10,345,000	...	...	...	10,112,000	...	9,828,000	9,581,000	8,735,000	7,472,000	6,758,000	...	...
175	11,931,000	...	...	...	11,729,000	...	...	11,274,000	10,567,000	9,537,000	8,110,000	5,949,000	...
200	13,522,000	...	...	...	13,346,000	...	...	12,941,000	12,335,000	11,476,000	10,308,000	8,710,000	...
225	15,102,000	...	...	...	14,906,000	...	...	14,590,000	...	13,264,000	12,310,000	10,990,000	6,695,000
250	16,687,000	...	...	...	16,548,000	...	...	16,226,000	...	15,083,000	14,211,000	13,099,000	9,783,000
275	18,272,000	...	...	...	18,140,000	...	...	17,849,000	...	16,813,000	...	15,064,000	12,291,000
300	19,858,000	...	...	...	19,738,000	...	...	19,466,000	...	18,525,000	...	16,946,000	14,539,000
325	21,437,000	...	...	...	21,322,000	...	...	21,077,000	...	20,211,000	...	18,778,000	16,636,000
350	23,022,000	...	...	...	22,915,000	...	...	22,687,000	...	21,879,000	...	20,565,000	18,632,000
375	24,601,000	...	...	...	24,500,000	...	...	24,292,000	...	23,540,000	...	22,321,000	20,552,000
400	26,180,000	...	...	...	26,092,000	...	...	25,833,000	...	25,189,000	...	24,052,000	22,422,000

CAPACITY, IN CUBIC FEET, OF 8″ PIPE LINE 15 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	773,000												
20	1,444,000	1,263,000	928,000										
30	2,088,000	1,929,000	1,727,000	1,459,000	1,031,000								
40	2,640,000	2,527,000	2,377,000	2,186,000	1,949,000	1,629,000							
50	3,187,000	3,094,000	2,976,000	2,826,000	2,640,000	2,419,000	1,784,000						
60	3,729,000	3,646,000	3,548,000	3,419,000		3,094,000	2,630,000	1,929,000					
70	4,260,000			3,997,000		3,718,000	3,342,000	2,821,000					
80	4,786,000			4,554,000		4,317,000	3,997,000	3,569,000					
90	5,317,000			5,106,000		4,894,000	4,611,000	4,255,000	2,785,000				
100	5,843,000			5,647,000		5,441,000	5,157,000	4,894,000	3,693,000				
125	7,148,000				6,921,000		6,638,000	6,395,000	5,529,000	4,116,000			
150	8,448,000				8,257,000		8,025,000	7,824,000	7,133,000	6,101,000	5,518,000		
175	9,743,000				9,578,000			9,206,000	8,629,000	7,788,000	6,622,000	4,858,000	
200	11,043,000				10,898,000			10,568,000	10,073,000	9,371,000	8,417,000	7,112,000	
225	12,332,000				12,172,000			11,914,000		10,831,000	10,052,000	8,974,000	5,467,000
250	13,627,000				13,513,000			13,250,000		12,317,000	11,605,000	10,697,000	7,989,000
275	14,921,000				14,813,000			14,576,000		13,730,000		12,301,000	10,037,000
300	16,216,000				16,118,000			15,896,000		15,128,000		13,838,000	11,873,000
325	17,505,000				17,413,000			17,211,000		16,505,000		15,334,000	13,585,000
350	18,800,000				18,712,000			18,527,000		17,866,000		16,794,000	15,215,000
375	20,090,000				20,007,000			19,837,000		19,223,000		18,228,000	16,783,000
400	21,379,000				21,307,000			21,095,000		20,569,000		19,641,000	18,310,000

CAPACITY, IN CUBIC FEET, OF 8″ PIPE LINE 20 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	669,000												
20	1,250,000	1,093,000	803,000										
30	1,808,000	1,669,000	1,495,000	1,263,000	892,000								
40	2,286,000	2,187,000	2,058,000	1,893,000	1,687,000	1,410,000							
50	2,759,000	2,678,000	2,576,000	2,446,000	2,286,000	2,094,000	1,544,000						
60	3,228,000	3,156,000	3,071,000	2,960,000		2,678,000	2,277,000	1,669,000					
70	3,688,000			3,460,000		3,219,000	2,893,000	2,442,000					
80	4,143,000			3,912,000		3,737,000	3,460,000	3,089,000					
90	4,603,000			4,420,000		4,237,000	3,991,000	3,683,000	2,411,000				
100	5,058,000			4,889,000		4,710,000	4,461,000	4,237,000	3,196,000				
125	6,188,000				5,991,000		5,746,000	5,536,000	4,786,000	3,562,000			
150	7,313,000				7,148,000		6,947,000	6,773,000	6,174,000	5,281,000	4,777,000		
175	8,134,000				8,291,000			7,969,000	7,469,000	6,741,000	5,732,000	4,205,000	
200	9,559,000				9,434,000			9,148,000	8,719,000	8,112,000	7,286,000	6,157,000	
225	10,675,000				10,537,000			10,313,000		9,376,000	8,702,000	7,768,000	4,732,000
250	11,796,000				11,698,000			11,470,000		10,662,000	10,046,000	9,260,000	6,916,000
275	12,916,000				12,823,000			12,617,000		11,885,000		10,648,000	8,688,000
300	14,037,000				13,952,000			13,760,000		13,095,000		11,979,000	10,278,000
325	15,153,000				15,073,000			14,899,000		14,287,000		13,274,000	11,760,000
350	16,274,000				16,198,000			16,037,000		15,466,000		14,537,000	13,171,000
375	17,390,000				17,319,000			17,172,000		16,640,000		15,778,000	14,528,000
400	18,507,000				18,444,000			18,261,000		17,806,000		17,002,000	15,850,000

CAPACITY, IN CUBIC FEET, OF 8″ PIPE LINE 30 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	546,000	....	....	....	....	....	....	....	....	....	....	....	....
20	1,019,000	892,000	655,000	....	....	....	....	....	....	....	....	....	....
30	1,474,000	1,366,000	1,219,000	1,030,000	728,000	....	....	....	....	....	....	....	....
40	1,864,000	1,784,000	1,678,000	1,543,000	1,376,000	1,150,000	....	....	....	....	....	....	....
50	2,250,000	2,184,000	2,100,000	1,995,000	1,864,000	1,707,000	1,259,000	....	....	....	....	....	....
60	2,632,000	2,574,000	2,505,000	2,414,000	....	2,184,000	1,857,000	1,361,000	....	....	....	....	....
70	3,007,000	....	....	2,821,000	....	2,625,000	2,359,000	1,991,000	....	....	....	....	....
80	3,379,000	....	....	3,215,000	....	3,047,000	2,821,000	2,519,000	....	....	....	....	....
90	3,754,000	....	....	3,604,000	....	3,455,000	3,255,000	3,003,000	1,966,000	....	....	....	....
100	4,125,000	....	....	3,987,000	....	3,841,000	3,641,000	3,455,000	2,607,000	....	....	....	....
125	5,046,000	....	....	....	4,886,000	....	4,686,000	4,515,000	3,903,000	2,905,000	....	....	....
150	5,964,000	....	....	....	5,829,000	....	5,665,000	5,523,000	5,035,000	4,307,000	3,896,000	....	....
175	6,878,000	....	....	....	6,761,000	....	....	6,499,000	6,091,000	5,498,000	4,675,000	3,430,000	....
200	7,795,000	....	....	....	7,693,000	....	....	7,460,000	7,111,000	6,616,000	5,942,000	5,021,000	....
225	8,701,000	....	....	....	8,593,000	....	....	8,411,000	....	7,646,000	7,096,000	6,335,000	3,859,000
250	9,620,000	....	....	....	9,539,000	....	....	9,354,000	....	8,695,000	8,192,000	7,551,000	5,640,000
275	10,533,000	....	....	....	10,457,000	....	....	10,290,000	....	9,692,000	....	8,684,000	7,085,000
300	11,447,000	....	....	....	11,378,000	....	....	11,222,000	....	10,679,000	....	9,769,000	8,382,000
325	12,358,000	....	....	....	12,292,000	....	....	12,150,000	....	11,651,000	....	10,825,000	9,590,000
350	13,272,000	....	....	....	13,210,000	....	....	13,079,000	....	12,613,000	....	11,855,000	10,741,000
375	14,182,000	....	....	....	14,124,000	....	....	14,004,000	....	13,570,000	....	12,868,000	11,848,000
400	15,092,000	....	....	....	15,041,000	....	....	14,892,000	....	14,521,000	....	13,865,000	12,926,000

CAPACITY, IN CUBIC FEET, OF 8″ PIPE LINE 40 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	473,000	...	...	...	...	...	...	...	...	...	...	...	...
20	884,000	773,000	568,000	...	...	...	...	...	...	...	...	...	...
30	1,279,000	1,181,000	1,057,000	893,000	631,000	...	...	...	...	...	...	...	...
40	1,616,000	1,547,000	1,455,000	1,339,000	1,193,000	997,000	...	...	...	...	...	...	...
50	1,951,000	1,894,000	1,822,000	1,730,000	1,616,000	1,481,000	1,092,000	...	...	...	...	...	...
60	2,283,000	2,232,000	2,172,000	2,093,000	...	1,894,000	1,610,000	1,181,000	...	...	...	...	...
70	2,608,000	...	...	2,447,000	...	2,276,000	2,046,000	1,727,000	...	...	...	...	...
80	2,930,000	...	...	2,788,000	...	2,643,000	2,447,000	2,185,000	...	...	...	...	...
90	3,256,000	...	...	3,126,000	...	2,997,000	2,823,000	2,605,000	1,705,000	...	...	...	...
100	3,578,000	...	...	3,458,000	...	3,331,000	3,158,000	2,997,000	2,261,000	...	...	...	...
125	4,377,000	...	...	...	4,238,000	...	4,064,000	3,916,000	3,385,000	2,520,000	...	...	...
150	5,172,000	...	...	...	5,056,000	...	4,914,000	4,790,000	4,367,000	3,736,000	3,379,000	...	...
175	5,965,000	...	...	...	5,864,000	...	...	5,637,000	5,283,000	4,768,000	4,055,000	2,974,000	...
200	6,761,000	...	...	...	6,673,000	...	...	6,470,000	6,167,000	5,738,000	5,154,000	4,355,000	...
225	7,551,000	...	...	...	7,453,000	...	...	7,295,000	...	6,632,000	6,155,000	5,495,000	3,347,000
250	8,343,000	...	...	...	8,274,000	...	...	8,113,000	...	7,541,000	7,105,000	6,549,000	4,891,000
275	9,136,000	...	...	...	9,070,000	...	...	8,924,000	...	8,406,000	...	7,532,000	6,145,000
300	9,929,000	...	...	...	9,869,000	...	...	9,733,000	...	9,262,000	...	8,473,000	7,269,000
325	10,718,000	...	...	...	10,661,000	...	...	10,538,000	...	10,105,000	...	9,389,000	8,318,000
350	11,511,000	...	...	...	11,457,000	...	...	11,343,000	...	10,939,000	...	10,282,000	9,316,000
375	12,300,000	...	...	...	12,250,000	...	...	12,146,000	...	11,770,000	...	11,160,000	10,276,000
400	13,090,000	...	...	...	13,046,000	...	...	12,916,000	...	12,594,000	...	12,026,000	11,211,000

CAPACITY, IN CUBIC FEET, OF 8″ PIPE LINE 50 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	423,000	....	....	....	....	....	....	....	....	....	....	....	....
20	790,000	691,000	508,000	....	....	....	....	....	....	....	....	....	....
30	1,143,000	1,055,000	945,000	799,000	564,000	....	....	....	....	....	....	....	....
40	1,445,000	1,383,000	1,301,000	1,197,000	1,067,000	892,000	....	....	....	....	....	....	....
50	1,744,000	1,694,000	1,629,000	1,547,000	1,445,000	1,324,000	976,000	....	....	....	....	....	....
60	2,041,000	1,996,000	1,942,000	1,871,000	....	1,694,000	1,439,000	1,055,000	....	....	....	....	....
70	2,332,000	....	....	2,188,000	....	2,035,000	1,829,000	1,544,000	....	....	....	....	....
80	2,620,000	....	....	2,493,000	....	2,363,000	2,188,000	1,953,000	....	....	....	....	....
90	2,910,000	....	....	2,795,000	....	2,679,000	2,524,000	2,329,000	1,524,000	....	....	....	....
100	3,198,000	....	....	3,091,000	....	2,978,000	2,823,000	2,679,000	2,021.000	....	....	....	....
125	3,913,000	....	....	....	3,789,000	....	3,633,000	3,501,000	3,026,000	2,253,000	....	....	....
150	4,624,000	....	....	....	4,520,000	....	4,393,000	4,283,000	3.904,000	3,340,000	3,021,000	....	....
175	5,333,000	....	....	....	5,243,000	....	....	5,039,000	4,723,000	4,263,000	3,625,000	2,659,000	....
200	6,044,000	....	....	....	5,965,000	....	....	5,785,000	5,514,000	5,130,000	4,607,000	3,893,000	....
225	6,750,000	....	....	....	6,663,000	....	....	6,522,000	....	5,929,000	5,502,000	4,912,000	2,992,000
250	7,459,000	....	....	....	7,397,000	....	....	7,253,000	....	6,742,000	6,352,000	5,855,000	4,373,000
275	8,168,000	....	....	....	8,108,000	....	....	7,978,000	....	7,515,000	....	6,733,000	5,494,000
300	8,876,000	....	....	....	8,823,000	....	....	8,701.000	....	8,281,000	....	7,575,000	6,499,000
325	9,582,000	....	....	....	9,531,000	....	....	9,421,000	....	9,034,000	....	8,393.000	7,436.000
350	10,291,000	....	....	....	10,243,000	....	....	10,141,000	....	9,780,000	....	9,192,000	8,329,000
375	10,997,000	....	....	....	10,951,000	....	....	10,858,000	....	10,522,000	....	9,977,000	9,187,000
400	11,702,000	....	....	....	11,663,000	....	....	11,547,000	....	11,259,000	....	10,751,000	10,023,000

CAPACITY, IN CUBIC FEET, OF 8″ PIPE LINE 70 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	357,000	....	....	....	....	....	....	....	....	....	....	....	....
20	667,000	584,000	429,000	....	....	....	....	....	....	....	....	....	....
30	965,000	891,000	798,000	674,000	476,000	....	....	....	....	....	....	....	....
40	1,220,000	1,168,000	1,098,000	1,010,000	901,000	753,000	....	....	....	....	....	....	....
50	1,473,000	1,430,000	1,375,000	1,306,000	1,220,000	1,118,000	824,000	....	....	....	....	....	....
60	1,723,000	1,685,000	1,640,000	1,580,000	....	1,430,000	1,215,000	891,000	....	....	....	....	....
70	1,969,000	....	....	1,847,000	....	1,718,000	1,544,000	1,303,000	....	....	....	....	....
80	2,212,000	....	....	2,104,000	....	1,995,000	1,847,000	1,649,000	....	....	....	....	....
90	2,457,000	....	....	2,360,000	....	2,262,000	2,131,000	1,966,000	1,287,000	....	....	....	....
100	2,700,000	....	....	2,610,000	....	2,515,000	2,383,000	2,262,000	1,706,000	....	....	....	....
125	3,304,000	....	....	....	3,199,000	....	3,068,000	2,956,000	2,555,000	1,902,000	....	....	....
150	3,904,000	....	....	....	3,816,000	....	3,709,000	3,616,000	3,296,000	2,820,000	2,550,000	....	....
175	4,503,000	....	....	....	4,426,000	....	....	4,255,000	3,988,000	3,599,000	3,060,000	2,245,000	....
200	5,103,000	....	....	....	5,007,000	....	....	4,884,000	4,655,000	4,331,000	3,890,000	3,287,000	....
225	5,699,000	....	....	....	5,626,000	....	....	5,506,000	....	5,006,000	4,646,000	4,147,000	2,526,000
250	6,298,000	....	....	....	6,245,000	....	....	6,124,000	....	5,692,000	5,363,000	4,944,000	3,692,000
275	6,896,000	....	....	....	6,846,000	....	....	6,736,000	....	6,345,000	....	5,685,000	4,639,000
300	7,494,000	....	....	....	7,449,000	....	....	7,347,000	....	6,991,000	....	6,396,000	5,487,000
325	8,090,000	....	....	....	8,048,000	....	....	7,955,000	....	7,628,000	....	7,087,000	6,279,000
350	8,689,000	....	....	....	8,648,000	....	....	8,562,000	....	8,257,000	....	7,761,000	7,032,000
375	9,285,000	....	....	....	9,247,000	....	....	9,168,000	....	8,884,000	....	8,424,000	7,757,000
400	9,881,000	....	....	....	9,847,000	....	....	9,750,000	....	9,506,000	....	9,077,000	8,462,000

CAPACITY, IN CUBIC FEET, OF 8″ PIPE LINE 100 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	299,000	....	....	....	....	....	....	....	....	....	....	....	....
20	558,000	488,000	359,000	....	....	....	....	....	....	....	....	....	....
30	808,000	746,000	668,000	564,000	399,000	....	....	....	....	....	....	....	....
40	1,021,000	977,000	900,000	846,000	745,000	630,000	....	....	....	....	....	....	....
50	1,233,000	1,197,000	1,131,000	1,093,000	1,021,000	936,000	690,000	....	....	....	....	....	....
60	1,442,000	1,411,000	1,353,000	1,323,000	....	1,197,000	1,017,000	746,000	....	....	....	....	....
70	1,648,000	....	....	1,546,000	....	1,438,000	1,293,000	1,091,000	....	....	....	....	....
80	1,852,000	....	....	1,762,000	....	1,670,000	1,546,000	1,381,000	....	....	....	....	....
90	2,057,000	....	....	1,975,000	....	1,894,000	1,784,000	1,646,000	1,077,000	....	....	....	....
100	2,261,000	....	....	2,185,000	....	2,105,000	1,995,000	1,894,000	1,428,000	....	....	....	....
125	2,766,000	....	....	....	2,678,000	....	2,568,000	2,474,000	2,139,000	1,592,000	....	....	....
150	3,269,000	....	....	....	3,195,000	....	3,105,000	3,027,000	2,760,000	2,361,000	2,135,000	....	....
175	3,770,000	....	....	....	3,706,000	....	....	3,562,000	3,338,000	3,013,000	2,562,000	1,880,000	....
200	4,273,000	....	....	....	4,217,000	....	....	4,089,000	3,897,000	3,626,000	3,257,000	2,752,000	....
225	4,771,000	....	....	....	4,710,000	....	....	4,610,000	....	4,191,000	3,889,000	3,472,000	2,115,000
250	5,272,000	....	....	....	5,228,000	....	....	5,127,000	....	4,765,000	4,490,000	4,139,000	3,091,000
275	5,773,000	....	....	....	5,731,000	....	....	5,640,000	....	5,312,000	....	4,759,000	3,883,000
300	6,274,000	....	....	....	6,236,000	....	....	6,151,000	....	5,853,000	....	5,354,000	4,591,000
325	6,773,000	....	....	....	6,737,000	....	....	6,659,000	....	6,386,000	....	5,933,000	5,256,000
350	7,274,000	....	....	....	7,240,000	....	....	7,168,000	....	6,913,000	....	6,498,000	5,887,000
375	7,773,000	....	....	....	7,741,000	....	....	7,675,000	....	7,438,000	....	7,053,000	6,494,000
400	8,272,000	....	....	....	8,244,000	....	....	8,162,000	....	7,959,000	....	7,600,000	7,085,000

CAPACITY, IN CUBIC FEET, OF 10″ PIPE LINE 10 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,674,000												
20	3,126,000	2,735,000	2,009,000										
30	4,521,000	4,175,000	3,740,000	3,159,000	2,233,000								
40	5,716,000	5,470,000	5,147,000	4,733,000	4,220,000	3,528,000							
50	6,899,000	6,699,000	6,442,000	6,118,000	5,716,000	5,236,000	3,863,000						
60	8,072,000	7,893,000	7,681,000	7,402,000		6,699,000	5,694,000	4,175,000					
70	9,222,000			8,652,000		8,049,000	7,234,000	6,107,000					
80	10,361,000			9,858,000		9,345,000	8,652,000	7,726,000					
90	11,511,000			11,053,000		10,595,000	9,981,000	9,211,000	6,029,000				
100	12,649,000			12,225,000		11,779,000	11,165,000	10,595,000	7,994,000				
125	15,474,000				14,983,000		14,369,000	13,844,000	11,968,000	8,909,000			
150	18,288,000				17,875,000		17,372,000	16,937,000	15,441,000	13,208,000	11,946,000		
175	21,090,000				20,733,000			19,929,000	18,679,000	16,859,000	14,335,000	10,517,000	
200	23,904,000				23,591,000			22,877,000	21,805,000	20,286,000	18,221,000	15,396,000	
225	26,695,000				26,349,000			25,791,000		23,446,000	21,760,000	19,427,000	11,834,000
250	29,497,000				29,252,000			28,682,000		26,662,000	25,121,000	23,156,000	17,295,000
275	32,300,000				32,065,000			31,552,000		29,721,000		26,628,000	21,727,000
300	35,102,000				34,890,000			34,410,000		32,746,000		29,955,000	25,701,000
325	37,894,000				37,715,000			37,257,000		35,728,000		33,193,000	29,408,000
350	40,696,000				40,506,000			40,104,000		38,675,000		36,353,000	32,936,000
375	43,487,000				43,309,000			42,940,000		41,611,000		39,457,000	36,330,000
400	46,278,000				46,122,000			45,664,000		44,526,000		42,516,000	39,635,000

CAPACITY, IN CUBIC FEET, OF 10″ PIPE LINE 20 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,183,000												
20	2,209,000	1,933,000	1,420,000										
30	3,196,000	2,951,000	2,643,000	2,233,000	1,578,000								
40	4,040,000	3,867,000	3,638,000	3,346,000	2,983,000	2,494,000							
50	4,877,000	4,735,000	4,553,000	4,325,000	4,040,000	3,701,000	2,730,000						
60	5,706,000	5,579,000	5,430,000	5,232,000		4,735,000	4,025,000	2,951,000					
70	6,519,000			6,116 000		5,690,000	5,114,000	4,317,000					
80	7,324,000			6,969,000		6,606,000	6,116,000	5,461,000					
90	8,137,000			7,813,000		7,489,000	7,055,000	6,511,000	4,261,000				
100	8,942,000			8,642,000		8,326,000	7,892,000	7,489,000	5,651,000				
125	10,939,000				10,591,000		10,157,000	9,786,000	8,460,000	6,298,000			
150	12,927,000				12,635,000		12,280,000	11,972,000	10,915,000	9,336,000	8,444,000		
175	14,908,000				14,656,000			14,088,000	13,204,000	11,917,000	10,133,000	7,434,000	
200	16,897,000				16,676,000			16,171,000	15,414,000	14,340,000	12,880,000	10,883,000	
225	18,870,000				18,626,000			18,231,000		16,573,000	15,382,000	13,732,000	8,366,000
250	20,852,000				20,678,000			20,275,000		18,847,000	17,758,000	16,369,000	12,225,000
275	22,833,000				22,667,000			22,304,000		21,009,000		18,823,000	15,358,000
300	24,814,000				24,664,000			24,324,000		23,148,000		21,175,000	18,168,000
325	26,787,000				26,660,000			26,337,000		25,256,000		23,464,000	20,788,000
350	28,768,000				28,633,000			28,349,000		27,339,000		25,697,000	23,282,000
375	30,741,000				30,615,000			30,354,000		29,415,000		27,892,000	25,682,000
400	32,714,000				32,603,000			32,280,000		31,475,000		30,054,000	28,018,000

CAPACITY, IN CUBIC FEET, OF 10″ PIPE LINE 30 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	965,000												
20	1,802,000	1,576,000	1,158,000										
30	2,606,000	2,407,000	2,156,000	1,821,000	1,287,000								
40	3,295,000	3,153,000	2,967,000	2,729,000	2,432,000	2,033,000							
50	3,977,000	3,861,000	3,713,000	3,527,000	3,295,000	3,018,000	2,227,000						
60	4,653,000	4,550,000	4,428,000	4,267,000		3,861,000	3,282,000	2,407,000					
70	5,316,000			4,988,000		4,640,000	4,170,000	3,520,000					
80	5,973,000			5,683,000		5,387,000	4,988,000	4,454,000					
90	6,636,000			6,372,000		6,108,000	5,754,000	5,310,000	3,475,000				
100	7,292,000			7,047,000		6,790,000	6,436,000	6,108,000	4,608,000				
125	8,920,000				8,637,000		8,283,000	7,981,000	6,899,000	5,136,000			
150	10,542,000				10,304,000		10,015,000	9,764,000	8,901,000	7,614,000	6,887,000		
175	12,158,000				11,952,000			11,489,000	10,768,000	9,719,000	8,264,000	6,063,000	
200	13,780,000				13,600,000			13,188,000	12,570,000	11,695,000	10,504,000	8,875,000	
225	15,389,000				15,190,000			14,868,000		13,516,000	12,544,000	11,199,000	6,822,000
250	17,005,000				16,863,000			16,535,000		15,370,000	14,482,000	13,349,000	9,970,000
275	18,620,000				18,485,000			18,189,000		17,133,000		15,351,000	12,525,000
300	20,236,000				20,114,000			19,837,000		18,878,000		17,269,000	14,816,000
325	21,845,000				21,726,000			21,478,000		20,596,000		19,135,000	16,953,000
350	23,461,000				23,351,000			23,119,000		22,296,000		20,957,000	18,987,000
375	25,070,000				24,967,000			24,754,000		23,988,000		22,746,000	20,944,000
400	26,679,000				26,589,000			26,325,000		25,668,000		24,510,000	22,849,000

CAPACITY, IN CUBIC FEET, OF 10″ PIPE LINE 50 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	748,000	....	....	....	....	....	....	....	....	....	....	....	....
20	1,397,000	1,222,000	898,000	....	....	....	....	....	....	....	....	....	....
30	2,021,000	1,866,000	1,671,000	1,412,000	998,000	....	....	....	....	....	....	....	....
40	2,555,000	2,445,000	2,300,000	2,116,000	1,886,000	1,577,000	....	....	....	....	....	....	....
50	3,084,000	2,994,000	2,879,000	2,735,000	2,555,000	2,340,000	1,726,000	....	....	....	....	....	....
60	3,608,000	3,528,000	3,433,000	3,309,000	....	2,994,000	2,545,000	1,866,000	....	....	....	....	....
70	4,122,000	....	....	3,868,000	....	3,598,000	3,234,000	2,730,000	....	....	....	....	....
80	4,631,000	....	....	4,407,000	....	4,177,000	3,868,000	3,453,000	....	....	....	....	....
90	5,145,000	....	....	4,941,000	....	4,736,000	4,461,000	4,117,000	2,695,000	....	....	....	....
100	5,654,000	....	....	5,465,000	....	5,265,000	4,991,000	4,736,000	3,573,000	....	....	....	....
125	6,917,000	....	....	....	6,697,000	....	6,423,000	6,188,000	5,350,000	3,982,000	....	....	....
150	8,175,000	....	....	....	7,990,000	....	7,765,000	7,571,000	6,902,000	5,904,000	5,340,000	....	....
175	9,427,000	....	....	....	9,268,000	....	....	8,908,000	8,349,000	7,536,000	6,408,000	4,701,000	....
200	10,685,000	....	....	....	10,545,000	....	....	10,226,000	9,747,000	9,068,000	8,145,000	6,882,000	....
225	11,933,000	....	....	....	11,778,000	....	....	11,529,000	....	10,481,000	9,727,000	8,684,000	5,290,000
250	13,186,000	....	....	....	13,076,000	....	....	12,821,000	....	11,918,000	11,229,000	10,351,000	7,731,000
275	14,438,000	....	....	....	14,334,000	....	....	14,104,000	....	13,286,000	....	11,903,000	9,712,000
300	15,691,000	....	....	....	15,596,000	....	....	15,382,000	....	14,638,000	....	13,390,000	11,489,000
325	16,939,000	....	....	....	16,849,000	....	....	16,654,000	....	15,971,000	....	14,838,000	13,146,000
350	18,192,000	....	....	....	18,107,000	....	....	17,927,000	....	17,288,000	....	16,250,000	14,723,000
375	19,439,000	....	....	....	19,360,000	....	....	19,195,000	....	18,601,000	....	17,638,000	16,240,000
400	20,687,000	....	....	....	20,617,000	....	....	20,413,000	....	19,904,000	....	19,005,000	17,718,000

CAPACITY, IN CUBIC FEET, OF 10″ PIPE LINE 100 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	529,000	...	...	...	...	...	...	...	...	...	...	...	...
20	987,000	865,000	635,000	...	...	...	...	...	...	...	...	...	...
30	1,428,000	1,319,000	1,181,000	998,000	705,000	...	...	...	...	...	...	...	...
40	1,806,000	1,728,000	1,626,000	1,495,000	1,333,000	1,114,000	...	...	...	...	...	...	...
50	2,180,000	2,116,000	2,035,000	1,933,000	1,806,000	1,654,000	1,220,000	...	...	...	...	...	...
60	2,550,000	2,494,000	2,427,000	2,339,000	...	2,116,000	1,799,000	1,319,000	...	...	...	...	...
70	2,914,000	...	...	2,734,000	...	2,543,000	2,286,000	1,929,000	...	...	...	...	...
80	3,273,000	...	...	3,115,000	...	2,952,000	2,734,000	2,441,000	...	...	...	...	...
90	3,637,000	...	...	3,492,000	...	3,348,000	3,154,000	2,910,000	1,905,000	...	...	...	...
100	3,997,000	...	...	3,863,000	...	3,722,000	3,528,000	3,348,000	2,526,000	...	...	...	...
125	4,889,000	...	...	...	4,734,000	...	4,540,000	4,374,000	3,782,000	2,815,000	...	...	...
150	5,778,000	...	...	...	5,648,000	...	5,489,000	5,351,000	4,879,000	4,173,000	3,774,000	...	...
175	6,661,000	...	...	...	6,551,000	...	...	6,297,000	5,902,000	5,327,000	4,529,000	3,323,000	...
200	7,553,000	...	...	...	7,454,000	...	...	7,228,000	6,890,000	6,410,000	5,757,000	4,865,000	...
225	8,435,000	...	...	...	8,326,000	...	...	8,149,000	...	7,408,000	6,876,000	6,138,000	3,739,000
250	9,320,000	...	...	...	9,243,000	...	...	9,063,000	...	8,424,000	7,938,000	7,317,000	5,464,000
275	10,206,000	...	...	...	10,132,000	...	...	9,970,000	...	9,391,000	...	8,414,000	6,865,000
300	11,092,000	...	...	...	11,025,000	...	...	10,873,000	...	10,347,000	...	9,465,000	8,121,000
325	11,974,000	...	...	...	11,910,000	...	...	11,772,000	...	11,289,000	...	10,488,000	9,292,000
350	12,859,000	...	...	...	12,799,000	...	...	12,672,000	...	12,220,000	...	11,487,000	10,407,000
375	13,741,000	...	...	...	13,685,000	...	...	13,568,000	...	13,148,000	...	12,467,000	11,480,000
400	14,623,000	...	...	...	14,574,000	...	...	14,429,000	...	14,069,000	...	13,434,000	12,524,000

CAPACITY, IN CUBIC FEET, OF 10″ PIPE LINE 150 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	432,000	....	....	....	....	....	....	....	....	....	....	....	....
20	806,000	705,000	518,000	....	....	....	....	....	....	....	....	....	....
30	1,166,000	1,077,000	964,000	815,000	576,000	....	....	....	....	....	....	....	....
40	1,474,000	1,411,000	1,327,000	1,221,000	1,088,000	910,000	....	....	....	....	....	....	....
50	1,780,000	1,728,000	1,662,000	1,578,000	1,474,000	1,350,000	996,000	....	....	....	....	....	....
60	2,082,000	2,036,000	1,981,000	1,909,000	....	1,728,000	1,469,000	1,077,000	....	....	....	....	....
70	2,379,000	....	....	2,232,000	....	2,076,000	1,866,000	1,575,000	....	....	....	....	....
80	2,673,000	....	....	2,543,000	....	2,410,000	2,232,000	1,993,000	....	....	....	....	....
90	2,969,000	....	....	2,851,000	....	2,733,000	2,575,000	2,376,000	1,555,000	....	....	....	....
100	3,263,000	....	....	3,154,000	....	3,038,000	2,880,000	2,733,000	2,062,000	....	....	....	....
125	3,992,000	....	....	....	3,865,000	....	3,707,000	3,571,000	3,087,000	2,298,000	....	....	....
150	4,718,000	....	....	....	4,611,000	....	4,482,000	4,369,000	3,983,000	3,407,000	3,082,000	....	....
175	5,441,000	....	....	....	5,349,000	....	....	5,141,000	4,819,000	4,349,000	3,698,000	2,713,000	....
200	6,167,000	....	....	....	6,086,000	....	....	5,902,000	5,625,000	5,233,000	4,700,000	3,972,000	....
225	6,887,000	....	....	....	6,797,000	....	....	6,653,000	....	6,049,000	5,614,000	5,012,000	3,053,000
250	7,610,000	....	....	....	7,546,000	....	....	7,400,000	....	6,878,000	6,481,000	5,974,000	4,461,000
275	8,333,000	....	....	....	8,272,000	....	....	8,140,000	....	7,667,000	....	6,869,000	5,605,000
300	9,056,000	....	....	....	9,001,000	....	....	8,877,000	....	8,448,000	....	7,728,000	6,630,000
325	9,776,000	....	....	....	9,724,000	....	....	9,612,000	....	9,217,000	....	8,563,000	7,587,000
350	10,499,000	....	....	....	10,450,000	....	....	10,346,000	....	9,978,000	....	9,378,000	8,497,000
375	11,219,000	....	....	....	11,173,000	....	....	11,078,000	....	10,735,000	....	10,179,000	9,387,000
400	11,939,000	....	....	....	11,899,000	....	....	11,781,000	....	11,487,000	....	10,968,000	10,225,000

CAPACITY, IN CUBIC FEET, OF 12″ PIPE LINE 10 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	2,660,000	...	...	...	...	...	...	...	...	...	...	...	...
20	4,966,000	4,345,000	3,192,000	...	...	...	...	...	...	...	...	...	...
30	7,183,000	6,633,000	5,941,000	5,019,000	3,547,000	...	...	...	...	...	...	...	...
40	9,081,000	8,690,000	8,176,000	7,520,000	6,704,000	5,604,000	...	...	...	...	...	...	...
50	10,961,000	10,641,000	10,233,000	9,719,000	9,081,000	8,318,000	6,136,000	...	...	...	...	...	...
60	12,823,000	12,539,000	12,202,000	11,759,000	...	10,641,000	9,045,000	6,633,000	...	...	...	...	...
70	14,650,000	...	...	13,745,000	...	12,787,000	11,493,000	9,701,000	...	...	...	...	...
80	16,459,000	...	...	15,661,000	...	14,845,000	13,745,000	12,273,000	...	...	...	...	...
90	18,286,000	...	...	17,559,000	...	16,831,000	15,856,000	14,632,000	9,577,000	...	...	...	...
100	20,095,000	...	...	19,421,000	...	18,711,000	17,736,000	16,831,000	12,699,000	...	...	...	...
125	24,582,000	...	...	...	23,802,000	...	22,826,000	21,993,000	19,013,000	14,153,000	...	...	...
150	29,052,000	...	...	...	28,395,000	...	27,597,000	26,906,000	24,529,000	20,982,000	18,977,000	...	...
175	33,504,000	...	...	...	32,936,000	...	...	31,659,000	29,672,000	26,781,000	22,773,000	16,707,000	...
200	37,973,000	...	...	...	37,477,000	...	...	36,341,000	34,639,000	32,227,000	28,945,000	24,458,000	...
225	42,407,000	...	...	...	41,857,000	...	...	40,971,000	...	37,246,000	34,568,000	30,861,000	18,800,000
250	46,859,000	...	...	...	46,469,000	...	...	45,564,000	...	42,354,000	39,906,000	36,785,000	27,473,000
275	51,311,000	...	...	...	50,938,000	...	...	50,123,000	...	47,214,000	...	42,301,000	34,515,000
300	55,763,000	...	...	...	55,426,000	...	...	54,663,000	...	52,020,000	...	47,586,000	40,829,000
325	60,197,000	...	...	...	59,913,000	...	...	59,186,000	...	56,756,000	...	52,730,000	46,717,000
350	64,649,000	...	...	...	64,347,000	...	...	63,709,000	...	61,438,000	...	57,749,000	52,322,000
375	69,083,000	...	...	...	68,799,000	...	...	68,214,000	...	66,103,000	...	62,680,000	57,714,000
400	73,517,000	...	...	...	73,269,000	...	...	72,541,000	...	70,732,000	...	67,540,000	62,964,000

CAPACITY, IN CUBIC FEET, OF 12″ PIPE LINE 20 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,880,000	....	....	....	....	....	....	....	....	....	....	....	....
20	3,510,000	3,071,000	2,256,000	....	....	....	....	....	....	....	....	....	....
30	5,077,000	4,689,000	4,200,000	3,548,000	2,507,000	....	....	....	....	....	....	....	....
40	6,419,000	6,143,000	5,779,000	5,316,000	4,739,000	3,961,000	....	....	....	....	....	....	....
50	7,748,000	7,522,000	7,234,000	6,870,000	6,419,000	5,880,000	4,338,000	....	....	....	....	....	....
60	9,064,000	8,864,000	8,626,000	8,312,000	....	7,522,000	6,394,000	4,689,000	....	....	....	....	....
70	10,356,000	....	....	9,716,000	....	9,039,000	8,124,000	6,858,000	....	....	....	....	....
80	11,635,000	....	....	11,070,000	....	10,494,000	9,716,000	8,676,000	....	....	....	....	....
90	12,926,000	....	....	12,412,000	....	11,898,000	11,208,000	10,343,000	6,770,000	....	....	....	....
100	14,205,000	....	....	13,728,000	....	13,227,000	12,537,000	11,898,000	8,977,000	....	....	....	....
125	17,377,000	....	....	....	16,825,000	....	16,136,000	15,546,000	13,440,000	10,005,000	....	....	....
150	20,536,000	....	....	....	20,073,000	....	19.508,000	19,019,000	17,339,000	14,832,000	13,415,000	....	....
175	23,683,000	....	....	....	23,282,000	....	....	22,379,000	20,975,000	18,932,000	16,098,000	11,810,000	....
200	26,843,000	....	....	....	26,492,000	....	....	25,689,000	24,486,000	22,781,000	20,461,000	17,289,000	....
225	29,977,000	....	....	....	29,589,000	....	....	28,962,000	....	26,329,000	24,436,000	21,815,000	13,290,000
250	33,124,000	....	....	....	32,849,000	....	....	32,209,000	....	29,940,000	28,210,000	26,003,000	19,421,000
275	36,271,000	....	....	....	36,008,000	....	....	35,431,000	....	33,375,000	....	29,902,000	24,398,000
300	39,418,000	....	....	....	39,180,000	....	....	38,641,000	....	36,773,000	....	33,638,000	28,862,000
325	42,553,000	....	....	....	42,352,000	....	....	41,838,000	....	40,120,000	....	37,274,000	33,024,000
350	45,700,000	....	....	....	45,487,000	....	....	45.035,000	....	43,430,000	....	40,823,000	36,986,000
375	48,834,000	....	....	....	48,634,000	....	....	48.220,000	....	46,728,000	....	44,308,000	40,798,000
400	51,969,000	....	....	....	51,793,000	....	....	51,279,000	....	50,000,000	....	47,743,000	44,509,000

CAPACITY, IN CUBIC FEET, OF 12″ PIPE LINE 30 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,533,000	....	....	....	....	....	....	....	....	....	....	....	....
20	2,862,000	2,505,000	1,840,000	....	....	....	....	....	....	....	....	....	....
30	4,141,000	3,824,000	3,425,000	2,893,000	2,044,000	....	....	....	....	....	....	....	....
40	5,235,000	5,010,000	4,713,000	4,335,000	3,864,000	3,231,000	....	....	....	....	....	....	....
50	6,318,000	6,134,000	5,899,000	5,603,000	5,235,000	4,795,000	3,537,000	....	....	....	....	....	....
60	7,392,000	7,228,000	7,034,000	6,779,000	....	6,134,000	5,214,000	3,824,000	....	....	....	....	....
70	8,445,000	....	....	7,924,000	....	7,372,000	6,625,000	5,592,000	....	....	....	....	....
80	9,488,000	....	....	9,028,000	....	8,558,000	7,924,000	7,075,000	....	....	....	....	....
90	10,541,000	....	....	10,122,000	....	9,703,000	9,140,000	8,435,000	5,521,000	....	....	....	....
100	11,584,000	....	....	11,196,000	....	10,787,000	10,224,000	9,703,000	7,320,000	....	....	....	....
125	14,171,000	....	....	....	13,721,000	....	13,159,000	12,678,000	10,960,000	8,159,000	....	....	....
150	16,748,000	....	....	....	16,369,000	....	15,909,000	15,511,000	14,140,000	12,095,000	10,940,000	....	....
175	19,314,000	....	....	....	18,987,000	....	....	18,251,000	17,106,000	15,439,000	13,128,000	9,631,000	....
200	21,891,000	....	....	....	21,605,000	....	....	20,950,000	19,969,000	18,578,000	16,686,000	14,099,000	....
225	24,447,000	....	....	....	24,130,000	....	....	23,619,000	....	21,472,000	19,928,000	17,791,000	10,838,000
250	27,013,000	....	....	....	26,788,000	....	....	26,267,000	....	24,416,000	23,005,000	21,206,000	15,838,000
275	29,580,000	....	....	....	29,365,000	....	....	28,895,000	....	27,218,000	....	24,386,000	19,897,000
300	32,146,000	....	....	....	31,952,000	....	....	31,512,000	....	29,989,000	....	27,433,000	23,537,000
325	34,702,000	....	....	....	34,539,000	....	....	34,120,000	....	32,719,000	....	30,398,000	26,932,000
350	37,269,000	....	....	....	37,095,000	....	....	36,727,000	....	35,418,000	....	33,291,000	30,163,000
375	39,825 000	....	....	....	39,661,000	....	....	39,324,000	....	38,107,000	....	36,134,000	33,271,000
400	42,381,000	....	....	....	42,238,000	....	....	41,819,000	....	40,776,000	....	38,936,000	36,298,000

CAPACITY, IN CUBIC FEET, OF 12″ PIPE LINE 50 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,189,000												
20	2,219,000	1,942,000	1,427,000										
30	3,211,000	2,965,000	2,656,000	2,243,000	1,585,000								
40	4,059,000	3,884,000	3,655,000	3,361,000	2,996,000	2,505,000							
50	4,899,000	4,757,000	4,574,000	4,344,000	4,059,000	3,718,000	2,743,000						
60	5,732,000	5,605,000	5,454,000	5,256,000		4,757,000	4,043,000	2,965,000					
70	6,548,000			6,144,000		5,716,000	5,137,000	4,336,000					
80	7,357,000			7,000,000		6,636,000	6,144,000	5,486,000					
90	8,174,000			7,849,000		7,524,000	7,088,000	6,541,000	4,281,000				
100	8,982,000			8,681,000		8,364,000	7,928,000	7,524,000	5,676,000				
125	10,988,000				10,640,000		10,203,000	9,831,000	8,499,000	6,326,000			
150	12,986,000				12,693,000		12,336,000	12,027,000	10,965,000	9,379,000	8,483,000		
175	14,976,000				14,723,000			14,152,000	13,264,000	11,972,000	10,180,000	7,468,000	
200	16,974,000				16,752,000			16,245,000	15,484,000	14,406,000	12,939,000	10,933,000	
225	18,957,000				18,711,000			18,314,000		16,649,000	15,452,000	13,795,000	8,404,000
250	20,947,000				20,772,000			20,368,000		18,933,000	17,839,000	16,443,000	12,281,000
275	22,937,000				22,770,000			22,405,000		21,105,000		18,909,000	15,428,000
300	24,927,000				24,776,000			24,435,000		23,254,000		21,272,000	18,251,000
325	26,909,000				26,766,000			26,457,000		25,371,000		23,571,000	20,883,000
350	28,899,000				28,764,000			28,479,000		27,464,000		25,815,000	23,389,000
375	30,881,000				30,754,000			30,493,000		29,549,000		28,019,000	25,799,000
400	32,863,000				32,752,000			32,427,000		31,618,000		30,191,000	28,146,000

CAPACITY, IN CUBIC FEET, OF 12″ PIPE LINE 100 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	840,000	...	...	...	...	...	...	...	...	...	...	...	...
20	1,569,000	1,373,000	1,008,000	...	...	...	...	...	...	...	...	...	...
30	2,269,000	2,096,000	1,877,000	1,586,000	1,120,000	...	...	...	...	...	...	...	...
40	2,869,000	2,746,000	2,583,000	2,376,000	2,118,000	1,770,000	...	...	...	...	...	...	...
50	3,463,000	3,362,000	3,233,000	3,071,000	2,869,000	2,628,000	1,939,000	...	...	...	...	...	...
60	4,051,000	3,962,000	3,855,000	3,715,000	...	3,362,000	2,851,000	2,096,000	...	...	...	...	...
70	4,629,000	...	...	4,343,000	...	4,040,000	3,631,000	3,065,000	...	...	...	...	...
80	5,200,000	...	...	4,948,000	...	4,690,000	4,343,000	3,878,000	...	...	...	...	...
90	5,778,000	...	...	5,548,000	...	5,318,000	5,010,000	4,623,000	3,026,000	...	...	...	...
100	6,349,000	...	...	6,136,000	...	5,912,000	5,604,000	5,318,000	4,012,000	...	...	...	...
125	7,767,000	...	...	...	7,521,000	...	7,212,000	6,949,000	6,007,000	4,472,000	...	...	...
150	9,180,000	...	...	...	8,972,000	...	8,720,000	8,501,000	7,750,000	6,630,000	5,996,000	...	...
175	10,586,000	...	...	...	10,407,000	...	...	10,003,000	9,376,000	8,462,000	7,196,000	5,279,000	...
200	11,999,000	...	...	...	11,812,000	...	...	11,483,000	10,945,000	10,183,000	9,146,000	7,728,000	...
225	13,400,000	...	...	...	13,266,000	...	...	12,946,000	...	11,769,000	10,922,000	9,751,000	5,940,000
250	14,806,000	...	...	...	14,683,000	...	...	14,397,000	...	13,383,000	12,609,000	11,623,000	8,681,000
275	16,213,000	...	...	...	16,095,000	...	...	15,838,000	...	14,918,000	...	13,366,000	10,996,000
300	17,620,000	...	...	...	17,513,000	...	...	17,272,000	...	16,437,000	...	15,036,000	12,901,000
325	19,021,000	...	...	...	18,920,000	...	...	18,701,000	...	17,934,000	...	16,661,000	14,761,000
350	20,428,000	...	...	...	20,332,000	...	...	20,131,000	...	19,413,000	...	18,247,000	16,532,000
375	21,829,000	...	...	...	21,739,000	...	...	21,554,000	...	20,887,000	...	19,805,000	18,236,000
400	23,230,000	...	...	...	23,151,000	...	...	22,921,000	...	22,350,000	...	21,341,000	19,895,000

CAPACITY, IN CUBIC FEET, OF 12″ PIPE LINE 150 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	686,000	....	....	....	....	....	....	....	....	....	....	....	....
20	1,281,000	1,121,000	823,000	....	....	....	....	....	....	....	....	....	....
30	1,853,000	1,711,000	1,532,000	1,294,000	915,000	....	....	....	....	....	....	....	....
40	2,342,000	2,242,000	2,109,000	1,940,000	1,729,000	1,445,000	....	....	....	....	....	....	....
50	2,827,000	2,745,000	2,640,000	2,507,000	2,342,000	2,146,000	1,583,000	....	....	....	....	....	....
60	3,308,000	3,235,000	3,148,000	3,033,000	....	2,745,000	2,333,000	1,711,000	....	....	....	....	....
70	3,779,000	....	....	3,546,000	....	3,299,000	2,965,000	2,502,000	....	....	....	....	....
80	4,246,000	....	....	4,040,000	....	3,829,000	3,546,000	3,166,000	....	....	....	....	....
90	4,717,000	....	....	4,530,000	....	4,342,000	4,090,000	3,775,000	2,470,000	....	....	....	....
100	5,184,000	....	....	5,010,000	....	4,827,000	4,575,000	4,342,000	3,276,000	....	....	....	....
125	6,342,000	....	....	....	6,140,000	....	5,889,000	5,673,000	4,905,000	3,651,000	....	....	....
150	7,495,000	....	....	....	7,325,000	....	7,119,000	6,941,000	6,328,000	5,413,000	4,896,000	....	....
175	8,643,000	....	....	....	8,497,000	....	....	8,167,000	7,655,000	6,909,000	5,875,000	4,310,000	....
200	9,796,000	....	....	....	9,668,000	....	....	9,375,000	8,936,000	8,314,000	7,467,000	6,310,000	....
225	10,940,000	....	....	....	10,798,000	....	....	10,570,000	....	9,609,000	8,918,000	7,961,000	4,850,000
250	12,089,000	....	....	....	11,988,000	....	....	11,755,000	....	10,927,000	10,295,000	9,490,000	7,087,000
275	13,237,000	....	....	....	13,141,000	....	....	12,931,000	....	12,180,000	....	10,913,000	8,904,000
300	14,386,000	....	....	....	14,299,000	....	....	14,102,000	....	13,420,000	....	12,276,000	10,533,000
325	15,530,000	....	....	....	15,447,000	....	....	15,269,000	....	14,642,000	....	13,603,000	12,052,000
350	16,678,000	....	....	....	16,601,000	....	....	16,436,000	....	15,850,000	....	14,898,000	13,498,000
375	17,822,000	....	....	....	17,749,000	....	....	17,598,000	....	17,054,000	....	16,170,000	14,889,000
400	18,966,000	....	....	....	18,902,000	....	....	18,715,000	....	18,248,000	....	17,424,000	16,244,000

CAPACITY, IN CUBIC FEET, OF 16″ PIPE LINE 20 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	3,467,000												
20	6,471,000	5,662,000	4,160,000										
30	9,361,000	8,644,000	7,743,000	6,541,000	4,622,000								
40	11,834,000	11,325,000	10,655,000	9,800,000	8,736,000	7,303,000							
50	14,284,000	13,868,000	13,336,000	12,666,000	11,834,000	10,840,000	7,997,000						
60	16,711,000	16,341,000	15,902,000	15,324,000		13,868,000	11,787,000	8,644,000					
70	19,091,000			17,913,000		16,664,000	14,977,000	12,643,000					
80	21,449,000			20,409,000		19,346,000	17,913,000	15,994,000					
90	23,830,000			22,882,000		21,934,000	20,663,000	19,068,000	12,481,000				
100	26,187,000			25,309,000		24,384,000	23,113,000	21,934,000	16,549,000				
125	32,035,000				31,018,000		29,747,000	28,660,000	24,777,000	18,444,000			
150	37,860,000				37,005,000		35,964,000	35,063,000	31,966,000	27,343,000	24,731,000		
175	43,661,000				42,922,000			41,257,000	38,669,000	34,901,000	29,677,000	21,773,000	
200	49,486,000				48,839,000			47,359,000	45,141,000	41,997,000	37,721,000	31,873,000	
225	55,264,000				54,548,000			53,392,000		48,538,000	45,048,000	40,217,000	24,500,000
250	61,066,000				60,557,000			59,379,000		55,195,000	52,005,000	47,937,000	35,803,000
275	66,867,000				66,382,000			65,319,000		61,528,000		55,126,000	44,979,000
300	72,669,000				72,230,000			71,237,000		67,792,000		62,011,000	53,207,000
325	78,447,000				78,078,000			77,130,000		73,963,000		68,717,000	60,881,000
350	84,249,000				83,856,000			83,024,000		80,065,000		75,258,000	68,185,000
375	90,027,000				89,658,000			88,895,000		86,141,000		81,683,000	75,211,000
400	95,806,000				95,482,000			94,535,000		92,177,000		88,016,000	82,053,000

Above table based on outside diameter of 16-inch pipe, or inside diameter of 15¼ inches.

CAPACITY, IN CUBIC FEET, OF 16″ PIPE LINE 30 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	2,827,000												
20	5,277,000	4,618,000	3,392,000										
30	7,634,000	7,049,000	6,314,000	5,334,000	3,769,000								
40	9,651,000	9,236,000	8,689,000	7,992,000	7,125,000	5,956,000							
50	11,649,000	11,309,000	10,876,000	10,329,000	9,651,000	8,840,000	6,521,000						
60	13,628,000	13,320,000	12,968,000	12,497,000		11,309,000	9,613,000	7,049,000					
70	15,569,000			14,608,000		13,590,000	12,214,000	10,310,000					
80	17,492,000			16,644,000		15,777,000	14,608,000	13,043,000					
90	19,434,000			18,661,000		17,888,000	16,851,000	15,551,000	10,178,000				
100	21,356,000			20,640,000		19,886,000	18,849,000	17,888,000	13,496,000				
125	26,125,000				25,296,000		24,259,000	23,373,000	20,206,000	15,042,000			
150	30,875,000				30,178,000		29,330,000	28,594,000	26,069,000	22,299,000	20,169,000		
175	35,607,000				35,003,000			33,646,000	31,535,000	28,463,000	24,203,000	17,756,000	
200	40,357,000				39,829,000			38,623,000	36,813,000	34,249,000	30,762,000	25,993,000	
225	45,069,000				44,485,000			43,542,000		39,584,000	36,738,000	32,798,000	19,980,000
250	49,800,000				49,386,000			48,424,000		45,013,000	42,411,000	39,094,000	29,198,000
275	54,532,000				54,136,000			53,269,000		50,177,000		44,956,000	36,681,000
300	59,263,000				58,905,000			58,094,000		55,286,000		50,573,000	43,392,000
325	63,975,000				63,674,000			62,901,000		60,319,000		56,040,000	49,650,000
350	68,707,000				68,386,000			67,708,000		65,295,000		61,374,000	55,606,000
375	73,419,000				73,117,000			72,495,000		70,252,000		66,614,000	61,336,000
400	78,132,000				77,868,000			77,095,000		75,172,000		71,779,000	66,916,000

Above table based on outside diameter of 16-inch pipe, or inside diameter of 15¼ inches.

CAPACITY, IN CUBIC FEET, OF 16″ PIPE LINE 50 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	2,192,000												
20	4,092,000	3,581,000	2,630,000										
30	5,919,000	5,466,000	4,896,000	4,136,000	2,923,000								
40	7,483,000	7,162,000	6,738,000	6,197,000	5,525,000	4,618,000							
50	9,032,000	8,769,000	8,433,000	8,009,000	7,483,000	6,855,000	5,057,000						
60	10,567,000	10,333,000	10,056,000	9,690,000		8,769,000	7,454,000	5,466,000					
70	12,073,000			11,327,000		10,538,000	9,471,000	7,995,000					
80	13,564,000			12,906,000		12,234,000	11,327,000	10,114,000					
90	15,069,000			14,470,000		13,871,000	13,067,000	12,058,000	7,892,000				
100	16,560,000			16,005,000		15,420,000	14,616,000	13,871,000	10,465,000				
125	20,258,000				19,615,000		18,811,000	18,124,000	15,668,000	11,663,000			
150	23,941,000				23,401,000		22,743,000	22,173,000	20,214,000	17,291,000	15,639,000		
175	27,610,000				27,142,000			26,090,000	24,453,000	22,070,000	18,767,000	13,768,000	
200	31,293,000				30,884,000			29,949,000	28,546,000	26,558,000	23,854,000	20,156,000	
225	34,948,000				34,494,000			33,764,000		30,694,000	28,487,000	25,432,000	15,493,000
250	38,616,000				38,295,000			37,549,000		34,904,000	32,887,000	30,314,000	22,640,000
275	42,285,000				41,978,000			41,306,000		38,909,000		34,860,000	28,443,000
300	45,954,000				45,676,000			45,048,000		42,870,000		39,216,000	33,647,000
325	49,608,000				49,374,000			48,775,000		46,772,000		43,454,000	38,499,000
350	53,277,000				53,028,000			52,502,000		50,631,000		47,591,000	43,118,000
375	56,931,000				56,697,000			56,215,000		54,475,000		51,654,000	47,562,000
400	60,585,000				60,380,000			59,871,000		58,290,000		55,659,000	51,888,000

Above table based on outside diameter of 16-inch pipe, or inside diameter of 15¼ inches.

CAPACITY, IN CUBIC FEET, OF 16″ PIPE LINE 100 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,549,000	....	....	....	....	....	....	....	....	....	....	....	....
20	2,892,000	2,531,000	1,859,000	....	....	....	....	....	....	....	....	....	....
30	4,184,000	3,864,000	3,461,000	2,923,000	2,066,000	....	....	....	....	....	....	....	....
40	5,289,000	5,062,000	4,763,000	4,380,000	3,905,000	3,264,000	....	....	....	....	....	....	....
50	6,385,000	6,199,000	5,961,000	5,661,000	5,289,000	4,845,000	3,574,000	....	....	....	....	....	....
60	7,470,000	7,304,000	7,108,000	6,850,000	....	6,199,000	5,269,000	3,864,000	....	....	....	....	....
70	8,534,000	....	....	8,007,000	....	7,449,000	6,695,000	5,651,000	....	....	....	....	....
80	9,588,000	....	....	9,123,000	....	8,647,000	8,007,000	7,149,000	....	....	....	....	....
90	10,652,000	....	....	10,228,000	....	9,805,000	9,236,000	8,523,000	5,579,000	....	....	....	....
100	11,706,000	....	....	11,313,000	....	10,900,000	10,332,000	9,805,000	7,397,000	....	....	....	....
125	14,320,000	....	....	....	13,865,000	....	13,297,000	12,811,000	11,075,000	8,244,000	....	....	....
150	16,923,000	....	....	....	16,541,000	....	16,076,000	15,673,000	14,289,000	12,222,000	11,055,000	....	....
175	19,517,000	....	....	....	19,186,000	....	....	18,442,000	17,285,000	15,601,000	13,266,000	9,732,000	....
200	22,120,000	....	....	....	21,831,000	....	....	21,170,000	20,178,000	18,773,000	16,861,000	14,247,000	....
225	24,703,000	....	....	....	24,383,000	....	....	23,866,000	....	21,697,000	20,137,000	17,977,000	10,951,000
250	27,297,000	....	....	....	27,069,000	....	....	26,542,000	....	24,672,000	23,247,000	21,428,000	16,004,000
275	29,890,000	....	....	....	29,673,000	....	....	29,198,000	....	27,503,000	....	24,641,000	20,106,000
300	32,483,000	....	....	....	32,287,000	....	....	31,843,000	....	30,303,000	....	27,720,000	23,784,000
325	35,066,000	....	....	....	34,901,000	....	....	34,477,000	....	33,062,000	....	30,717,000	27,214,000
350	37,660,000	....	....	....	37,484,000	....	....	37,112,000	....	35,790,000	....	33,640,000	30,479,000
375	40,243,000	....	....	....	40,077.000	....	....	39,736,000	....	38,507,000	....	36,513,000	33,620,000
400	42,826,000	....	....	....	42,681,000	....	....	42,257,000	....	41.204,000	....	39,344,000	36,678,000

Above table based on outside diameter of 16-inch pipe, or inside diameter of 15¼ inches.

CAPACITY, IN CUBIC FEET, OF 16″ PIPE LINE 150 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,265,000	...	...	...	...	...	...	...	...	...	...	...	...
20	2,361,000	2,066,000	1,518,000	...	...	...	...	...	...	...	...	...	...
30	3,416,000	3,154,000	2,825,000	2,387,000	1,687,000	...	...	...	...	...	...	...	...
40	4,319,000	4,133,000	3,888,000	3,576,000	3,188,000	2,665,000	...	...	...	...	...	...	...
50	5,213,000	5,061,000	4,867,000	4,622,000	4,319,000	3,956,000	2,918,000	...	...	...	...	...	...
60	6,099,000	5,964,000	5,803,000	5,592,000	...	5,061,000	4,302,000	3,154,000	...	...	...	...	...
70	6,967,000	...	...	6,537,000	...	6,082,000	5,466,000	4,614,000	...	...	...	...	...
80	7,828,000	...	...	7,448,000	...	7,060,000	6,537,000	5,837,000	...	...	...	...	...
90	8,697,000	...	...	8,351,000	...	8,005,000	7,541,000	6,959,000	4,555,000	...	...	...	...
100	9,557,000	...	...	9,237,000	...	8,899,000	8,435,000	8,005,000	6,039,000	...	...	...	...
125	11,691,000	...	...	...	11,320,000	...	10,856,000	10,460,000	9,043,000	6,731,000	...	...	...
150	13,817,000	...	...	...	13,505,000	...	13,125,000	12,796,000	11,666,000	9,979,000	9,026,000	...	...
175	15,935,000	...	...	...	15,665,000	...	...	15,057,000	14,112,000	12,737,000	10,831,000	7,946,000	...
200	18,060,000	...	...	...	17,824,000	...	...	17,284,000	16,474,000	15,327,000	13,767,000	11,632,000	...
225	20,169,000	...	...	...	19,908,000	...	...	19,486,000	...	17,714,000	16,441,000	14,678,000	8,941,000
250	22,287,000	...	...	...	22,101,000	...	...	21,671,000	...	20,144,000	18,980,000	17,195,000	13,066,000
275	24,404,000	...	...	...	24,227,000	...	...	23,839,000	...	22,455,000	...	20,119,000	16,415,000
300	26,521,000	...	...	...	26,361,000	...	...	25,998,000	...	24,741,000	...	22,632,000	19,418,000
325	28,630,000	...	...	...	28,495,000	...	...	28,149,000	...	26,994,000	...	25,079,000	22,219,000
350	30,748,000	...	...	...	30,604,000	...	...	30,301,000	...	29,221,000	...	27,466,000	24,885,000
375	32,857,000	...	...	...	32,722,000	...	...	32,443,000	...	31,439,000	...	29,811,000	27,449,000
400	34,965,000	...	...	...	34,847,000	...	...	34,502,000	...	33,641,000	...	32,123,000	29,946,000

Above table based on outside diameter of 16-inch pipe, or inside diameter of 15¼ inches.

CAPACITY, IN CUBIC FEET, OF 16″ PIPE LINE 200 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,093,000	....	....	....	....	....	....	....	....	....	....	....	....
20	2,040,000	1,785,000	1,311,000	....	....	....	....	....	....	....	....	....	....
30	2,951,000	2,725,000	2,441,000	2,062,000	1,457,000	....	....	....	....	....	....	....	....
40	3,731,000	3,570,000	3,359,000	3,089,000	2,754,000	2,302,000	....	....	....	....	....	....	....
50	4,503,000	4,372,000	4,205,000	3,993,000	3,731,000	3,417,000	2,521,000	....	....	....	....	....	....
60	5,269,000	5,152,000	5,013,000	4,831,000	....	4,372,000	3,716,000	2,725,000	....	....	....	....	....
70	6,019,000	....	....	5,647,000	....	5,254,000	4,722,000	3,986,000	....	....	....	....	....
80	6,762,000	....	....	6,435,000	....	6,099,000	5,647,000	5,043,000	....	....	....	....	....
90	7,513,000	....	....	7,214,000	....	6,916,000	6,515,000	6,012,000	3,935,000	....	....	....	....
100	8,256,000	....	....	7,980,000	....	7,688,000	7,287,000	6,916,000	5,217,000	....	....	....	....
125	10,100,000	....	....	....	9,780,000	....	9,379,000	9,036,000	7,812,000	5,815,000	....	....	....
150	11,937,000	....	....	....	11,667,000	....	11,339,000	11,055,000	10,078,000	8,621,000	7,797,000	....	....
175	13,766,000	....	....	....	13,533,000	....	....	13,008,000	12,192,000	11,004,000	9,357,000	6,865,000	....
200	15,602,000	....	....	....	15,398,000	....	....	14,932,000	14,232,000	13,241,000	11,893,000	10,049,000	....
225	17,424,000	....	....	....	17,198,000	....	....	16,834,000	....	15,304,000	14,203,000	12,680,000	7,724,000
250	19,254,000	....	....	....	19,093,000	....	....	18,722,000	....	17,403,000	16,397,000	15,114,000	11,288,000
275	21,083,000	....	....	....	20,930,000	....	....	20,595,000	....	19,399,000	....	17,381,000	14,181,000
300	22,912,000	....	....	....	22,774,000	....	....	22,460,000	....	21,374,000	....	19,552,000	16,776,000
325	24,734,000	....	....	....	24,617,000	....	....	24,319,000	....	23,320,000	....	21,666,000	19,195,000
350	26,563,000	....	....	....	26,439,000	....	....	26,177,000	....	25,244,000	....	23,728,000	21,498,000
375	28,385,000	....	....	....	28,268,000	....	....	28,028,000	....	27,161,000	....	25,754,000	23,714,000
400	30,207,000	....	....	....	30,105,000	....	....	29,806,000	....	29,063,000	....	27,751,000	25,871,000

Above table based on outside diameter of 16-inch pipe, or inside diameter of 15¼ inches.

CAPACITY, IN CUBIC FEET, OF 18″ PIPE LINE 20 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	4,769,000												
20	8,902,000	7,789,000	5,723,000										
30	12,877,000	11,891,000	10,651,000	8,998,000	6,359,000								
40	16,279,000	15,579,000	14,657,000	13,481,000	12,018,000	10,047,000							
50	19,649,000	19,077,000	18,346,000	17,423,000	16,279,000	14,912,000	11,001,000						
60	22,988,000	22,479,000	21,875,000	21,080,000		19,077,000	16,215,000	11,891,000					
70	26,263,000			24,641,000		22,924,000	20,603,000	17,392,000					
80	29,506,000			28,075,000		26,612,000	24,641,000	22,002,000					
90	32,781,000			31,477,000		30,173,000	28,425,000	26,231,000	17,169,000				
100	36,024,000			34,816,000		33,544,000	31,795,000	30,173,000	22,765,000				
125	44,068,000				42,669,000		40,920,000	39,426,000	34,084,000	25,372,000			
150	52,081,000				50,904,000		49,473,000	48,233,000	43,973,000	37,614,000	34,021,000		
175	60,061,000				59,014,000			56,754,000	53,193,000	48,011,000	40,825,000	29,951,000	
200	68,074,000				67,183,000			65,148,000	62,096,000	57,772,000	51,890,000	43,845,000	
225	76,023,000				75,037,000			73,447,000		66,770,000	61,969,000	55,324,000	33,703,000
250	84,003,000				83,304,000			81,682,000		75,927,000	71,539,000	65,943,000	49,251,000
275	91,984,000				91,316,000			89,854,000		84,639,000		75,832,000	61,874,000
300	99,965,000				99,360,000			97,993,000		93,256,000		85,307,000	73,193,000
325	107,913,000				107,405,000			106,101,000		101,745,000		94,528,000	83,749,000
350	115,894,000				115,354,000			114,209,000		110,139,000		103,526,000	93,796,000
375	123,843,000				123,334,000			122,285,000		118,501,000		112,365,000	103,462,000
400	131,792,000				131,347,000			130,043,000		126,800,000		121,077,000	112,874,000

Above table based on outside diameter of 18-inch pipe, or inside diameter of 17¼ inches.

CAPACITY, IN CUBIC FEET, OF 18″ PIPE LINE 50 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	3,015,000												
20	5,629,000	4,926,000	3,619,000										
30	8,143,000	7,519,000	6,735,000	5,690,000	4,021,000								
40	10,295,000	9,852,000	9,269,000	8,525,000	7,600,000	6,353,000							
50	12,425,000	12,063,000	11,601,000	11,018,000	10,294,000	9,429,000	6,956,000						
60	14,537,000	14,215,000	13,833,000	13,330,000		12,063,000	10,254,000	7,519,000					
70	16,608,000			15,582,000		14,496,000	13,029,000	10,998,000					
80	18,658,000			17,754,000		16,829,000	15,582,000	13,913,000					
90	20,729,000			19,905,000		19,081,000	17,975,000	16,587,000	10,857,000				
100	22,780,000			22,016,000		21,212,000	20,106,000	19,081,000	14,396,000				
125	27,867,000				26,983,000		25,877,000	24,932,000	21,554,000	16,045,000			
150	32,934,000				32,190,000		31,285,000	30,501,000	27,807,000	23,786,000	21,514,000		
175	37,981,000				37,337,000			35,890,000	33,638,000	30,360,000	25,816,000	18,940,000	
200	43,048,000				42,485,000			41,198,000	39,268,000	36,533,000	32,813,000	27,727,000	
225	48,074,000				47,451,000			46,446,000		42,223,000	39,187,000	34,985,000	21,312,000
250	53,121,000				52,679,000			51,653,000		48,014,000	45,239,000	41,701,000	31,145,000
275	58,168,000				57,746,000			56,821,000		53,523,000		47,954,000	39,127,000
300	63,215,000				62,833,000			61,968,000		58,972,000		53,946,000	46,285,000
325	68,241,000				67,920,000			67,095,000		64,341,000		59,776,000	52,960,000
350	73,288,000				72,946,000			72,222,000		69,649,000		65,467,000	59,314,000
375	78,315,000				77,993,000			77,329,000		74,937,000		71,056,000	65,426,000
400	83,341,000				83,060,000			82,235,000		80,185,000		76,565,000	71,378,000

CAPACITY, IN CUBIC FEET, OF 18″ PIPE LINE 100 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	2,131,000	....	....	....	....	....	....	....	....	....	....	....	....
20	3,979,000	3,482,000	2,558,000	....	....	....	....	....	....	....	....	....	....
30	5,756,000	5,315,000	4,761,000	4,022,000	2,842,000	....	....	....	....	....	....	....	....
40	7,276,000	6,964,000	6,552,000	6,026,000	5,372,000	4,491,000	....	....	....	....	....	....	....
50	8,783,000	8,527,000	8,200,000	7,788,000	7,276,000	6,665,000	4,917,000	....	....	....	....	....	....
60	10,275,000	10,048,000	9,778,000	9,423,000	....	8,527,000	7,248,000	5,315,000	....	....	....	....	....
70	11,739,000	....	....	11,014,000	....	10,247,000	9,209,000	7,774,000	....	....	....	....	....
80	13,189,000	....	....	12,549,000	....	11,896,000	11,014,000	9,835,000	....	....	....	....	....
90	14,653,000	....	....	14,070,000	....	13,487,000	12,706,000	11,725,000	7,674,000	....	....	....	....
100	16,103,000	....	....	15,563,000	....	14,994,000	14,212,000	13,487,000	10,176,000	....	....	....	....
125	19,698,000	....	....	....	19,073,000	....	18,291,000	17,623,000	15,236,000	11,341,000	....	....	....
150	23,280,000	....	....	....	22,754,000	....	22,115,000	21,560,000	19,656,000	16,813,000	15,207,000	....	....
175	26,847,000	....	....	....	26,393,000	....	....	25,369,000	23,778,000	21,461,000	18,249,000	13,388,000	....
200	30,429,000	....	....	....	30,031,000	....	....	29,122,000	27,757,000	25,824,000	23,195,000	19,599,000	....
225	33,982,000	....	....	....	33,542,000	....	....	32,831,000	....	29,846,000	27,700,000	24,730,000	15,065,000
250	37,550,000	....	....	....	37,237,000	....	....	36,512,000	....	33,940,000	31,978,000	29,477,000	22,015,000
275	41,117,000	....	....	....	40,819,000	....	....	40,165,000	....	37,834,000	....	33,897,000	27,658,000
300	44,685,000	....	....	....	44,415,000	....	....	43,803,000	....	41,686,000	....	38,132,000	32,717,000
325	48,238,000	....	....	....	48,010,000	....	....	47,428,000	....	45,480,000	....	42,254,000	37,436,000
350	51,805,000	....	....	....	51,564,000	....	....	51,052,000	....	49,233,000	....	46,276,000	41,927,000
375	55,358,000	....	....	....	55,131,000	....	....	54,662,000	....	52,971,000	....	50,228,000	46,248,000
400	58,912,000	....	....	....	58,713,000	....	....	58,130,000	....	56,680,000	....	54,122,000	50,455,000

Above table based on outside diameter of 18-inch pipe, or inside diameter of 17¼ inches.

CAPACITY, IN CUBIC FEET, OF 18″ PIPE LINE 150 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure												
	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,740,000	....	....	....	....	....	....	....	....	....	....	....	....
20	3,249,000	2,843,000	2,088,000	....	....	....	....	....	....	....	....	....	....
30	4,699,000	4,340,000	3,887,000	3,284,000	2,320,000	....	....	....	....	....	....	....	....
40	5,941,000	5,686,000	5,349,000	4,920,000	4,386,000	3,666,000	....	....	....	....	....	....	....
50	7,171,000	6,962,000	6,695,000	6,359,000	5,941,000	5,442,000	4,015,000	....	....	....	....	....	....
60	8,389,000	8,204,000	7,983,000	7,693,000	....	6,962,000	5,918,000	4,340,000	....	....	....	....	....
70	9,585,000	....	....	8,993,000	....	8,366,000	7,519,000	6,347,000	....	....	....	....	....
80	10,768,000	....	....	10,246,000	....	9,712,000	8,993,000	8,030,000	....	....	....	....	....
90	11,964,000	....	....	11,488,000	....	11,012,000	10,374,000	9,573,000	6,266,000	....	....	....	....
100	13,147,000	....	....	12,706,000	....	12,242,000	11,604,000	11,012,000	8,308,000	....	....	....	....
125	16,083,000	....	....	....	15,630,000	....	14,934,000	14,389,000	12,439,000	9,260,000	....	....	....
150	19,007,000	....	....	....	18,578,000	....	18,056,000	17,603,000	16,048,000	13,727,000	12,416,000	....	....
175	21,920,000	....	....	....	21,549,000	....	....	20,713,000	19,413,000	17,522,000	14,899,000	10,931,000	....
200	24,844,000	....	....	....	24,519,000	....	....	23,777,000	22,663,000	21,085,000	18,938,000	16,002,000	....
225	27,745,000	....	....	....	27,386,000	....	....	26,805,000	....	24,369,000	22,616,000	20,191,000	12,300,000
250	30,658,000	....	....	....	30,403,000	....	....	29,811,000	....	27,711,000	26,109,000	24,067,000	17,975,000
275	33,571,000	....	....	....	33,327,000	....	....	32,793,000	....	30,890,000	....	27,676,000	22,581,000
300	36,483,000	....	....	....	36,263,000	....	....	35,764,000	....	34,035,000	....	31,134,000	26,713,000
325	39,384,000	....	....	....	39,199,000	....	....	38,723,000	....	37,133,000	....	34,499,000	30,565,000
350	42,297,000	....	....	....	42,100,000	....	....	41,682,000	....	40,197,000	....	37,783,000	34,232,000
375	45,198,000	....	....	....	45,013,000	....	....	44,630,000	....	43,249,000	....	41,009,000	37,760,000
400	48,099,000	....	....	....	47,937,000	....	....	47,461,000	....	46,277,000	....	44,189,000	41,195,000

Above table based on outside diameter of 18-inch pipe, or inside diameter of 17¼ inches.

CAPACITY, IN CUBIC FEET, OF 18″ PIPE LINE 200 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,503,000												
20	2,807,000	2,456,000	1,804,000										
30	4,060,000	3,749,000	3,358,000	2,837,000	2,005,000								
40	5,132,000	4,912,000	4,621,000	4,250,000	3,789,000	3,167,000							
50	6,195,000	6,015,000	5,784,000	5,493,000	5,132,000	4,701,000	3,468,000						
60	7,248,000	7,087,000	6,897,000	6,646,000		6,015,000	5,112,000	3,749,000					
70	8,280,000			7,769,000		7,228,000	6,496,000	5,483,000					
80	9,303,000			8,852,000		8,391,000	7,769,000	6,937,000					
90	10,335,000			9,924,000		9,513,000	8,962,000	8,270,000	5,413,000				
100	11,358,000			10,977,000		10,576,000	10,025,000	9,513,000	7,177,000				
125	13,894,000				13,453,000		12,902,000	12,431,000	10,746,000	8,000,000			
150	16,421,000				16,050,000		15,599,000	15,208,000	13,864,000	11,859,000	10,726,000		
175	18,937,000				18,616,000			17,894,000	16,771,000	15,137,000	12,872,000	9,443,000	
200	21,463,000				21,183,000			20,541,000	19,579,000	18,215,000	16,360,000	13,824,000	
225	23,970,000				23,659,000			23,157,000		21,052,000	19,538,000	17,443,000	10,626,000
250	26,486,000				26,265,000			25,574,000		23,939 000	22,556,000	20,792,000	15,528,000
275	29,002,000				28,792,000			28,330,000		26,686,000		23,909,000	19,508,000
300	31,518,000				31,328,000			30,897,000		29,403,000		26,897,000	23,077,000
325	34,025,000				33,864,000			33,453,000		32,080,000		29,804,000	26,406,000
350	36,541,000				36,371,000			36,010,000		34,726,000		32,641,000	29,574,000
375	39,047,000				38,887,000			38,556,000		37,363,000		35,428,000	32,621,000
400	41,554,000				41,413,000			41,002,000		39,980,000		38,175,000	35,589,000

Above table based on outside diameter of 18-inch pipe, or inside diameter of 17¼ inches.

CAPACITY, IN CUBIC FEET, OF 18″ PIPE LINE 250 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,347,000	....	....	....	....	....	....	....	....	....	....	....	....
20	2,514,000	2,200,000	1,616,000	....	....	....	....	....	....	....	....	....	....
30	3,637,000	3,359,000	3,008,000	2,541,000	1,796,000	....	....	....	....	....	....	....	....
40	4,598,000	4,401,000	4,140,000	3,808,000	3,395,000	2,838,000	....	....	....	....	....	....	....
50	5,550,000	5,389,000	5,182,000	4,921,000	4,598,000	4,212,000	3,107,000	....	....	....	....	....	....
60	6,493,000	6,350,000	6,179,000	5,954,000	....	5,389,000	4,580,000	3,359,000	....	....	....	....	....
70	7,418,000	....	....	6,960,000	....	6,475,000	5,820,000	4,912,000	....	....	....	....	....
80	8,335,000	....	....	7,930,000	....	7,517,000	6,960,000	6,215,000	....	....	....	....	....
90	9,260,000	....	....	8,891,000	....	8,523,000	8,029,000	7,409,000	4,850,000	....	....	....	....
100	10,176,000	....	....	9,834,000	....	9,475,000	8,981,000	8,523,000	6,430,000	....	....	....	....
125	12,448,000	....	....	....	12,053,000	....	11,559,000	11,137,000	9,628,000	7,167,000	....	....	....
150	14,712,000	....	....	....	14,379,000	....	13,975,000	13,625,000	12,421,000	10,625,000	9,610,000	....	....
175	16,966,000	....	....	....	16,679,000	....	....	16,032,000	15,026,000	13,562,000	11,532,000	8,460,000	....
200	19,229,000	....	....	....	18,978,000	....	....	18,403,000	17,541,000	16,319,000	14,658,000	12,385,000	....
225	21,475,000	....	....	....	21,196,000	....	....	20,747,000	....	18,861,000	17,505,000	15,628,000	9,520,000
250	23,729,000	....	....	....	23,532,000	....	....	23,073,000	....	21,448,000	20,208,000	18,628,000	13,912,000
275	25,984,000	....	....	....	25,795,000	....	....	25,382,000	....	23,909,000	....	21,421,000	17,478,000
300	28,238,000	....	....	....	28,067,000	....	....	27,681,000	....	26,343,000	....	24,097,000	20,675,000
325	30,483,000	....	....	....	30,340,000	....	....	29,971,000	....	28,741,000	....	26,702,000	23,657,000
350	32,738,000	....	....	....	32,585,000	....	....	32,262,000	....	31,112,000	....	29,244,000	26,496,000
375	34,983,000	....	....	....	34,840,000	....	....	34,543,000	....	33,474,000	....	31,741,000	29,226,000
400	37,229,000	....	....	....	37,103,000	....	....	36,735,000	....	35,819,000	....	34,202,000	31,885,000

Above table based on outside diameter of 18-inch pipe, or inside diameter of 17¼ inches.

CAPACITY, IN CUBIC FEET, OF 20″ PIPE LINE 20 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	6,291,000												
20	11,744,000	10,276,000	7,549,000										
30	16,986,000	15,686,000	14,050,000	11,869,000	8,388,000								
40	21,474,000	20,552,000	19,335,000	17,783,000	15,854,000	13,253,000							
50	25,920,000	25,165,000	24,201,000	22,984,000	21,474,000	19,671,000	14,512,000						
60	30,324,000	29,653,000	28,856,000	27,808,000		25,165,000	21,390,000	15,686,000					
70	34,644,000			32,505,000		30,240,000	27,179,000	22,942,000					
80	38,923,000			37,035,000		35,106,000	32,505,000	29,024,000					
90	43,243,000			41,523,000		39,803,000	37,497,000	34,602,000	22,649,000				
100	47,521,000			45,927,000		44,249,000	41,943,000	39,803,000	30,031,000				
125	58,132,000				56,287,000		53,980,000	52,009,000	44,962,000	33,470,000			
150	68,702,000				67,150,000		65,263,000	63,627,000	58,007,000	49,618,000	44,879,000		
175	79,230,000				77,888,000			74,868,000	70,170,000	63,333,000	53,854,000	39,510,000	
200	89,799,000				88,625,000			85,941,000	81,914,000	76,210,000	68,450,000	57,839,000	
225	100,285,000				98,985,000			96,888,000		88,080,000	81,746,000	72,980,000	44,459,000
250	110,813,000				109,890,000			107,751,000		100,159,000	94,371,000	86,989,000	64,969,000
275	121,341,000				120,460,000			118,530,000		111,652,000		100,034,000	81,621,000
300	131,868,000				131,071,000			129,268,000		123,018,000		112,533,000	96,552,000
325	142,354,000				141,683,000			139,963,000		134,217,000		124,696,000	110,477,000
350	152,882,000				152,169,000			150,659,000		145,290,000		136,566,000	123,731,000
375	163,367,000				162,696,000			161,312,000		156,321,000		148,226,000	136,482,000
400	173,853,000				173,266,000			171,546,000		167,268,000		159,718,000	148,897,000

Above table based on outside diameter of 20-inch pipe, or inside diameter of $19\frac{1}{4}$ inches.

CAPACITY, IN CUBIC FEET, OF 20″ PIPE LINE 50 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	3,978,000	....	....	....	....	....	....	....	....	....	....	....	....
20	7,426,000	6,498,000	4,774,000	....	....	....	....	....	....	....	....	....	....
30	10,742,000	9,919,000	8,885,000	7,506,000	5,304,000	....	....	....	....	....	....	....	....
40	13,580,000	12,996,000	12,227,000	11,246,000	10,025,000	8,381,000	....	....	....	....	....	....	....
50	16,391,000	15,914,000	15,304,000	14,534,000	13,580,000	12,439,000	9,177,000	....	....	....	....	....	....
60	19,176,000	18,752,000	18,248,000	17,585,000	....	15,914,000	13,527,000	9,919,000	....	....	....	....	....
70	21,908,000	....	....	20,555,000	....	19,123,000	17,187,000	14,508,000	....	....	....	....	....
80	24,613,000	....	....	23,420,000	....	22,200,000	20,555,000	18,354,000	....	....	....	....	....
90	27,345,000	....	....	26,258,000	....	25,170,000	23,712,000	21,881,000	14,322,000	....	....	....	....
100	30,051,000	....	....	29,043,000	....	27,982,000	26,523,000	25,170,000	18,990,000	....	....	....	....
125	36,761,000	....	....	....	35,594,000	....	34,135,000	32,889,000	28,433,000	21,165,000	....	....	....
150	43,445,000	....	....	....	42,464,000	....	41,270,000	40,236,000	36,682,000	31,377,000	28,380,000	....	....
175	50,103,000	....	....	....	49,254,000	....	....	47,344,000	44,373,000	40,050,000	34,056,000	24,985,000	....
200	56,787,000	....	....	....	56,044,000	....	....	54,346,000	51,800,000	48,193,000	43,286,000	36,576,000	....
225	63,417,000	....	....	....	62,595,000	....	....	61,269,000	....	55,699,000	51,694,000	46,151,000	28,115,000
250	70,075,000	....	....	....	69,491,000	....	....	68,139,000	....	63,338,000	59,678,000	55,009,000	41,085,000
275	76,732,000	....	....	....	76,175,000	....	....	74,955,000	....	70,605,000	....	63,258,000	51,614,000
300	83,390,000	....	....	....	82,886,000	....	....	81,745,000	....	77,793,000	....	71,162,000	61,057,000
325	90,021,000	....	....	....	89,596,000	....	....	88,509,000	....	84,875,000	....	78,854,000	69,863,000
350	96,678,000	....	....	....	96,227,000	....	....	95,272,000	....	91,877,000	....	86,360,000	78,244,000
375	103,309,000	....	....	....	102,885,000	....	....	102,009,000	....	98,853,000	....	93,734,000	86,307,000
400	109,940,000	....	....	....	109,568,000	....	....	108,481,000	....	105,776,000	....	101,001,000	94,158,000

Above table based on outside diameter of 20-inch pipe, or inside diameter of 19¼ inches.

CAPACITY, IN CUBIC FEET, OF 20″ PIPE LINE 100 MILES LONG, FOR 24 HOURS

Intake Pressure Lb. per Sq. In.	Discharge Pressure 5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	2,812,000												
20	5,249,000	4,593,000	3,374,000										
30	7,593,000	7,012,000	6,280,000	5,305,000	3,749,000								
40	9,599,000	9,186,000	8,643,000	7,949,000	7,087,000	5,924,000							
50	11,586,000	11,249,000	10,818,000	10,274,000	9,599,000	8,793,000	6,487,000						
60	13,555,000	13,255,000	12,899,000	12,430,000		11,249,000	9,561,000	7,012,000					
70	15,486,000			14,530,000		13,517,000	12,149,000	10,255,000					
80	17,398,000			16,555,000		15,692,000	14,530,000	12,974,000					
90	19,330,000			18,561,000		17,792,000	16,761,000	15,467,000	10,124,000				
100	21,242,000			20,529,000		19,779,000	18,748,000	17,792,000	13,424,000				
125	25,985,000				25,160,000		24,129,000	23,248,000	20,098,000	14,961,000			
150	30,710,000				30,016,000		29,173,000	28,441,000	25,929,000	22,179,000	20,061,000		
175	35,416,000				34,816,000			33,466,000	31,366,000	28,310,000	24,073,000	17,661,000	
200	40,141,000				39,616,000			38,416,000	36,616,000	34,066,000	30,598,000	25,854,000	
225	44,828,000				44,247,000			43,309,000		39,372,000	36,541,000	32,622,000	19,873,000
250	49,531,000				49,121,000			48,165,000		44,772,000	42,184,000	38,885,000	29,041,000
275	54,240,000				53,846,000			52,984,000		49,909,000		44,715,000	36,485,000
300	58,946,000				58,590,000			57,783,000		54,990,000		50,303,000	43,159,000
325	63,633,000				63,333,000			62,564,000		59,996,000		55,740,000	49,384,000
350	68,339,000				68,020,000			67,345,000		64,945,000		61,046,000	55,308,000
375	73,026,000				72,726,000			72,017,000		69,876,000		66,258,000	61,008,000
400	77,713,000				77,451,000			76,682,000		74,770,000		71,395,000	66,558,000

Above table based on outside diameter of 20-inch pipe, or inside diameter of 19¼ inches.

CAPACITY, IN CUBIC FEET, OF 20″ PIPE LINE 150 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	2,296,000												
20	4,286,000	3,750,000	2,755,000										
30	6,199,000	5,725,000	5,128,000	4,332,000	3,061,000								
40	7,837,000	7,500,000	7,056,000	6,490,000	5,786,000	4,837,000							
50	9,460,000	9,184,000	8,832,000	8,388,000	7,837,000	7,179,000	5,296,000						
60	11,067,000	10,822,000	10,531,000	10,149,000		9,184,000	7,806,000	5,725,000					
70	12,644,000			11,863,000		11,036,000	9,919,000	8,373,000					
80	14,205,000			13,516,000		12,812,000	11,863,000	10,592,000					
90	15,782,000			15,154,000		14,527,000	13,685,000	12,628,000	8,266,000				
100	17,343,000			16,762,000		16,149,000	15,307,000	14,527,000	10,960,000				
125	21,216,000				20,543,000		19,701,000	18,981,000	16,409,000	12,215,000			
150	25,074,000				24,507,000		23,818,000	23,221,000	21,170,000	18,109,000	16,379,000		
175	28,916,000				28,426,000			27,324,000	25,609,000	23,114,000	19,655,000	14,419,000	
200	32,773,000				32,345,000			31,365,000	29,896,000	27,814,000	24,982,000	21,109,000	
225	36,600,000				36,126,000			35,361,000		32,146,000	29,834,000	26,635,000	16,226,000
250	40,443,000				40,106,000			39,325,000		36,555,000	34,442,000	31,748,000	23,711,000
275	44,285,000				43,964,000			43,259,000		40,749,000		36,509,000	29,788,000
300	48,127,000				47,836,000			47,178,000		44,897,000		41,070,000	35,238,000
325	51,954,000				51,709,000			51,082,000		48,984,000		45,510,000	40,320,000
350	55,796,000				55,536,000			54,985,000		53,026,000		49,842,000	45,158,000
375	59,623,000				59,378,000			58,873,000		57,052.000		54,097,000	49,811,000
400	63,450,000				63,236,000			62,608,000		61,047,000		58,292,000	54,342,000

Above table based on outside diameter of 20-inch pipe, or inside diameter of 19¼ inches.

CAPACITY, IN CUBIC FEET, OF 20″ PIPE LINE 200 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,983,000												
20	3,702,000	3,240,000	2,380,000										
30	5,355,000	4,946,000	3,742,000	2,644,000									
40	6,770,000	6,480,000	6,096,000	5,607,000	4,998,000	4,178,000							
50	8,172,000	7,934,000	7,630,000	7,247,000	6,770,000	6,202,000	4,575,000						
60	9,561,000	9,349,000	9,098,000	8,767,000		7,934,000	6,744,000	4,946,000					
70	10,923,000			10,249,000		9,534,000	8,569,000	7,233,000					
80	12,272,000			11,677,000		11,068,000	10,249,000	9,151,000					
90	13,634,000			13,092,000		12,550,000	11,822,000	10,910,000	7,141,000				
100	14,983,000			14,480,000		13,951,000	13,224,000	12,550,000	9,468,000				
125	18,329,000				17,747,000		17,020,000	16,398,000	14,176,000	10,553,000			
150	21,661,000				21,172,000		20,577,000	20,061,000	18,289,000	15,644,000	14,150,000		
175	24,981,000				24,558,000			23,605,000	22,124,000	19,969,000	16,980,000	12,457,000	
200	28,313,000				27,943,000			27,097,000	25,827,000	24,029,000	21,582,000	18,236,000	
225	31,620,000				31,210,000			30,548,000		27,771,000	25,771,000	23,010,000	14,018,000
250	34,939,000				34,648,000			33,973,000		31,580,000	29,755,000	27,427,000	20,484,000
275	38,258,000				37,981,000			37,372,000		35,203,000		31,540,000	25,735,000
300	41,578,000				41,326,000			40,758,000		38,787,000		35,481,000	30,443,000
325	44,884,000				44,672,000			44,130,000		42,318,000		39,316,000	34,833,000
350	48,203,000				47,978,000			47,502,000		45,810,000		43,059,000	39,012,000
375	51,509,000				51,298,000			50,861,000		49,288,000		46,735,000	43,032,000
400	54,815,000				54,630,000			54,088,000		52,739,000		50,359,000	46,946,000

Above table based on outside diameter of 20-inch pipe, or inside diameter of 19¼ inches.

CAPACITY, IN CUBIC FEET, OF 20″ PIPE LINE 250 MILES LONG, FOR 24 HOURS

Intake Pressure	Discharge Pressure												
Lb. per Sq. In.	5 Lb.	10 Lb.	15 Lb.	20 Lb.	25 Lb.	30 Lb.	40 Lb.	50 Lb.	75 Lb.	100 Lb.	125 Lb.	150 Lb.	200 Lb.
10	1,777,000	....	....	....	....	....	....	....	....	....	....	....	....
20	3,317,000	2,902,000	2,132,000	....	....	....	....	....	....	....	....	....	....
30	4,798,000	4,431,000	3,969,000	3,353,000	2,369,000	....	....	....	....	....	....	....	....
40	6,066,000	5,805,000	5,462,000	5,023,000	4,478,000	3,744,000	....	....	....	....	....	....	....
50	7,322,000	7,108,000	6,836,000	6,492,000	6,066,000	5,556,000	4,099,000	....	....	....	....	....	....
60	8,566,000	8,376,000	8,151,000	7,855,000	....	7,322,000	6,042,000	4,431,000	....	....	....	....	....
70	9,786,000	....	....	9,182,000	....	8,542,000	7,677,000	6,480,000	....	....	....	....	....
80	10,995,000	....	....	10,461,000	....	9,916,000	7,855,000	8,198,000	....	....	....	....	....
90	12,215,000	....	....	11,729,000	....	11,243,000	10,592,000	9,775,000	6,398,000	....	....	....	....
100	13,424,000	....	....	12,973,000	....	12,499,000	11,848,000	11,243,000	8,483,000	....	....	....	....
125	16,421,000	....	....	....	15,900,000	....	15,248,000	14,691,000	12,701,000	9,454,000	....	....	....
150	19,407,000	....	....	....	18,968,000	....	18,435,000	17,973,000	16,386,000	14,016,000	12,677,000	....	....
175	22,381,000	....	....	....	22,002,000	....	....	21,149,000	19,822,000	17,890,000	15,213,000	11,162,000	....
200	25,366,000	....	....	....	25,035,000	....	....	24,276,000	23,139,000	21,528,000	19,336,000	16,338,000	....
225	28,329,000	....	....	....	27,961,000	....	....	27,369,000	....	24,881,000	23,092,000	20,615,000	12,559,000
250	31,302,000	....	....	....	31,042,000	....	....	30,438,000	....	28,293,000	26,658,000	24,573,000	18,352,000
275	34,276,000	....	....	....	34,028,000	....	....	33,483,000	....	31,539,000	....	28,257,000	23,056,000
300	37,250,000	....	....	....	37,025,000	....	....	36,516,000	....	34,750,000	....	31,788,000	27,274,000
325	40,212,000	....	....	....	40,023,000	....	....	39,537,000	....	37,914,000	....	35,224,000	31,208,000
350	43,186,000	....	....	....	42,985,000	....	....	42,558,000	....	41,042,000	....	38,577,000	34,952,000
375	46,148,000	....	....	....	45,959,000	....	....	45,568,000	....	44,158,000	....	41,871,000	38,554,000
400	49,110,000	....	....	....	48,944,000	....	....	48,559,000	....	47,250,000	....	45,117,000	42,061,000

Above table based on outside diameter of 20-inch pipe, or inside diameter of $19\frac{1}{4}$ inches.

PART SEVEN

Compression of Natural Gas

Description—A great many people not directly connected with the gas business are under the impression that compressing natural gas consists of "pumping" air into a gas line. This is erroneous. A compressor outfit consists of steam or gas driven compressors, with all necessary cooling systems and appurtenances for taking gas from the field or incoming gas lines, at a low or natural pressure, compressing and delivering it at a higher pressure to outgoing lines, in order to overcome the friction in the line enroute to the next compressing station or to the market.

If air were introduced into a gas line under pressure, there would be great liability of an explosion of the whole line, due to the air mixing with the gas and forming an explosive mixture found in a gas engine cylinder.

Object of Compressors—The distance of flow of natural gas from the gas well, is limited by the "rock pressure" or natural pressure. The higher the "rock pressure," the greater the distance a certain quantity of gas will flow from the well in a certain sized pipe line.

The two illustrations following give a very comprehensive idea of the advantage of the compressor.

The first illustration shows the comparative size of pipe necessary to carry three million cubic feet of gas in twenty-four hours, one hundred miles, with and without the aid of a compressor.

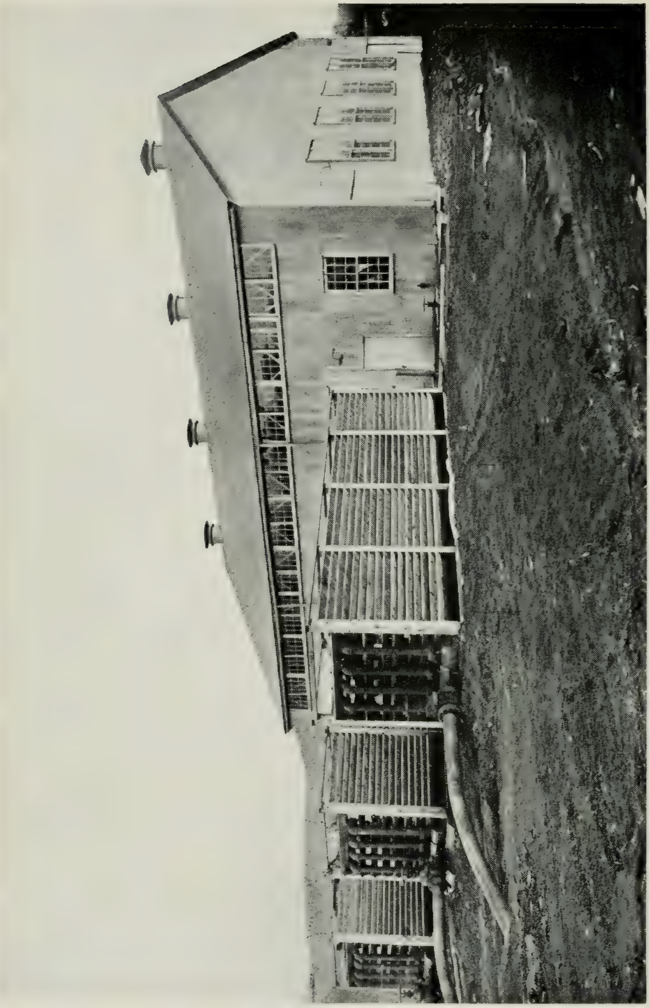


Fig. 113.—THOMAS COMPRESSING STATION—Note Cooling System on Discharge Lines

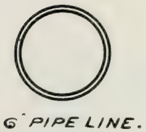


Fig. 114—With a compressor at the intake of 6" pipe line compressing gas to a pressure of 300 lb. and with 5 lb. at the discharge end it will require a 6" line.

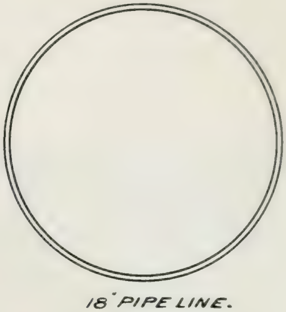


Fig. 115—Without compressor and gas at 14 lb. pressure at the intake of line, with 5 lb. pressure at the discharge end it will require an 18 inch line.

An eighteen-inch pipe line will cost to lay, including pipe, from ten to twelve times as much as a six-inch pipe line.

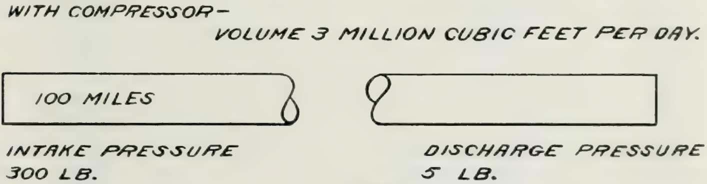


Fig. 116

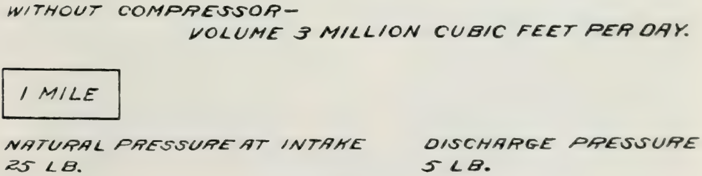


Fig. 117

Figure Nos. 116 and 117 shows the comparative lengths of two six-inch pipe lines, one being connected with a compressor and receiving its gas at 300-lb. pressure, and the

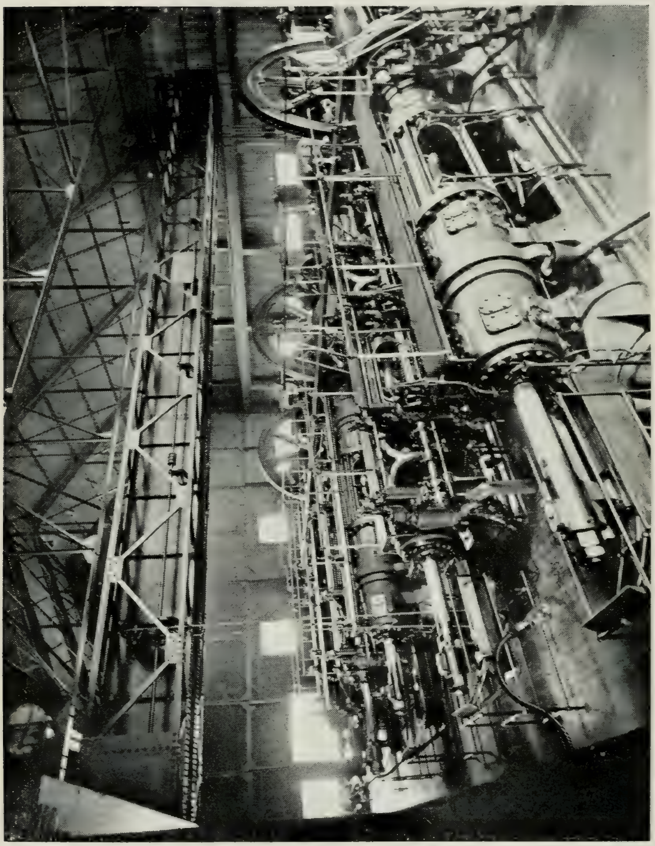


Fig. 118.—Waynesburg Compressing Station of the Manufacturers Light and Heat Company of Pittsburgh, Pa.

other receiving its gas from the field at a natural pressure of 25 lb., and both delivering three million cubic feet of gas per twenty-four hours at a 5 lb. discharge pressure.

When the natural pressure of gas in the field decreases to such an extent that it cannot be delivered at distant points without the employment of exceedingly large size lines, it is necessary to install compressors to raise the pressure. These can be driven either by steam or gas engine, either direct connected or belt drive. They can also be driven by electric motor, in which case, however, alternating current induction motors should be used, in order not to have any sparks in the compressor station, which would be the case if direct current commutator motors were used. Belt or rope drive can be employed, but direct connected compressors are preferable unless the units are so small that it would entail too high a speed for economical operation. If gas engines are adopted, using natural gas for fuel, it is good practice to have them so designed as to be capable of being converted into producer gas engines in case the price of gas should rise to a point sufficient to warrant using coal in a gas producer. The advisability of this, however, depends upon the availability and cost of coal in the locality of the plant.

The capacity of compressor cylinders of different diameters, is shown in the following table, based on an actual volumetric efficiency of 80 per cent. This table assumes that the intake pressure of the gas entering the compressor cylinder is at atmosphere and the measurement basis of the gas discharged from the compressor is also at atmosphere (14.4 pounds per square inch absolute.)

Quantity of gas, in cubic feet per 24 hours, compressed by cylinder of one inch stroke, running at one revolution per minute with intake pressure at 14.4 pounds per square inch absolute (equal to atmospheric pressure or 0 pounds gauge.)

10	99	21	454	32	1060
11	121	22	499	33	1130
12	144	23	545	34	1197
13	171	24	595	35	1270
14	199	25	646	36	1342
15	231	26	698	37	1418
16	262	27	753	38	1498
17	295	28	810	39	1577
18	333	29	869	40	1660
19	370	30	930		
20	410	31	995		

Fig. 119—EXTERIOR VIEW—GAS COMPRESSING STATION
Jefferson County Gas Company, Loleta, Pa. Note Cooling Tank. The pipes in the cooler are covered with water during operation.

To ascertain the quantity of gas compressed by a cylinder of any diameter, running at a given number of revolutions per minute, with the intake at atmosphere, multiply the number corresponding to the diameter, taken from the table, by the length of the stroke in inches and the number of revolutions per minute. If the intake pressure is at any value other than atmosphere, multiply the quantity as obtained above by the fraction,

$$\frac{p+14.4}{14.4}$$

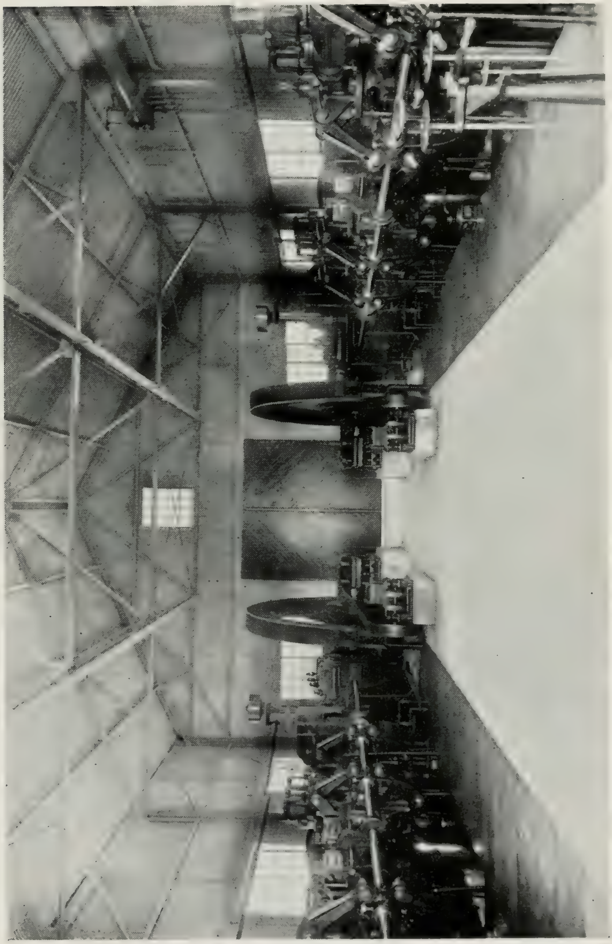


Fig. 120—COMPRESSOR INSTALLATION, CANEY RIVER GAS CO., COLLINSVILLE, OKLAHOMA
Two 400 h. p. Single Tandem Compressors.

where p is the actual intake pressure in the line in pounds per square inch gauge.

The power required to compress natural gas depends upon the ratio of intake to discharge pressure in pounds per square inch absolute. The following table shows the indicated horsepower required on the compressor piston to compress gas at the rate of 1,000,000 cubic feet per day, from various intake pressures to various discharge pressures. As will be seen from the table, when the range of pressures through which the gas is compressed becomes high, the power required is much less when two-stage compression is adopted, than when the gas is compressed through a single stage. The values in the following table must be increased by ten per cent. to ascertain the brake horse-power required from the engine. The power is directly proportional to the quantity of gas compressed.

In addition to the decreased power per million feet of gas required by two-stage compression over single-stage compression, a further advantage is obtained by the reduction of the temperature of the discharged gas. In fact, it is necessary to adopt two-stage compression when necessary to compress through a wide range of pressures in order to keep the temperatures from becoming injuriously high. The temperature rise due to the compressing of gas depends upon the ratio of the absolute pressure of discharge to intake, and not upon their actual values. For instance, the temperature rise is as great in compressing from atmosphere to 60 pounds as from 60 pounds to 360 pounds. In order to obtain the benefits of two-stage compression it is necessary to cool the gas after it leaves the first stage compressor and before entering the second stage. It is also advisable to cool it after leaving the high stage, for two reasons. First, this obviates injurious effects to sleeve couplings in the discharge line due to the high heat. Second, it condenses whatever liquid there may be thrown down by the gas due to its com-

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TABLE OF INDICATED HORSE-POWER ON THE COMPRESSOR PISTON PER MILLION CUBIC FEET OF NATURAL GAS PER DAY

Discharge Pressure, Pounds per Square Inch, Gauge

Suction Pressure	50		60		70		80		90		100		125		150		175		200	
	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage
10" Vac	111.3	107.0	123.0	114.0	133.7	121.6	144.3	128.2		133.8		139.0		150.0		159.6		168.0		176.0
5" Vac	96.0	95.8	105.7	103.0	115.1	110.5	124.0	116.0	132.8	121.0	141.3	126.2		137.8		146.4		154.6		162.2
0 Lb	84.3		93.8	93.8	102.0	100.0	110.0	106.0	117.5	111.2	125.0	116.0	142.7	127.4		136.2		144.6		151.4
5 Lb	67.0		75.3		82.8		89.5		96.0	95.8	102.2	100.2	116.8	110.2	130.3	120.0	143.5	127.8		134.5
10 Lb	54.5		62.5		69.5		75.9		81.8		88.8		100.0	98.2	112.0	107.6	123.0	114.6	133.8	122.0
15 Lb	44.6		52.5		59.0		65.4		71.0		76.3		88.0		98.5	97.6	108.3	105.6	118.0	111.6
20 Lb			44.0		50.8		56.9		62.3		67.4		78.6		88.3		97.5	97.0	106.0	103.4
25 Lb.					43.8		49.5		54.8		59.6		71.0		80.1		88.8		96.8	96.0
30 Lb							43.4		48.7		53.2		64.1		73.3		81.7		89.1	
35 Lb.									42.9		48.0		58.1		67.3		75.1		82.5	
40 Lb.											42.5		53.0		62.0		69.9		76.9	
45 Lb.													48.5		57.0		65.0		71.8	
50 Lb.													44.0		52.9		60.5		67.3	
60 Lb															45.1		52.9		59.1	
70 Lb																	45.9		52.8	
80 Lb																	40.2		46.5	
90 Lb.																			41.5	
100 Lb.																				
120 Lb																				
140 Lb.																				
160 Lb.																				
180 Lb																				
200 Lb.																				

Suction Pressure	225		250		275		300		325		350		375		400	
	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage
10" Vac		182.2		189.0		194.6		200.0		206.0		210.4		215.4		220.0
5" Vac		168.6		175.0		180.2		185.8		190.4		195.6		200.0		204.0
0 Lb		158.0		164.0		169.0		174.2		178.8		183.8		187.6		191.8
5 Lb		141.0		146.0		151.6		156.6		160.6		165.2		168.8		172.6
10 Lb	144.1	128.0		133.6		138.6		143.4		147.6		151.8		156.0		158.6
15 Lb	126.9	117.4	135.8	123.0	144.4	128.2		132.6		137.0		141.0		144.6		148.2
20 Lb	114.2	109.4	122.1	114.0	129.9	119.4	137.4	124.0	144.8	128.2		132.2		135.8		139.6
25 Lb.	104.2	102.0	111.4	107.2	118.5	112.0	125.2	116.2	132.0	120.6	138.3	124.6	144.9	128.4		131.8
30 Lb	96.1	95.6	103.0	100.6	109.4	106.0	115.8	110.0	121.9	114.0	127.5	118.0	133.6	121.8	139.3	125.6
35 Lb.	89.3		95.8	95.4	101.7	100.0	107.7	104.4	113.3	108.4	118.7	112.4	124.1	116.0	129.0	119.6
40 Lb.	83.3		89.4		95.2	94.8	100.7	99.0	106.1	103.6	111.2	107.2	116.3	110.2	121.2	114.0
45 Lb.	78.2		84.2		89.7		95.0	94.6	100.0	98.6	104.9	102.4	109.8	106.2	114.3	109.6
50 Lb.	73.5		79.1		84.7		89.7		94.8	94.6	99.3	98.0	103.9	101.8	108.2	105.4
60 Lb	65.3		71.1		76.2		81.0		85.5		90.0		94.1	94.0	98.2	97.6
70 Lb	58.2		64.0		69.1		73.6		78.2		82.2		86.1		90.1	
80 Lb	52.8		57.7		62.8		67.3		71.7		75.8		79.7		83.1	
90 Lb.	47.0		52.5		57.0		62.0		66.0		70.0		73.8		77.3	
100 Lb.	42.1		47.5		52.7		56.9		61.0		65.0		68.8		72.3	
120 Lb					43.9		48.4		52.7		56.0		59.8		63.1	
140 Lb.							41.0		45.0		48.8		52.2		55.2	
160 Lb.											42.2		45.8		49.0	
180 Lb													40.0		43.5	
200 Lb.															38.1	

pression, before these liquids have an opportunity to pass out into the main line where they would freeze and plug the line. It is therefore necessary, in addition to coolers, to provide the system with proper drips.

When gas is compressed through a pressure range not greater than three compressions, it is not necessary to employ a very extensive cooling system.

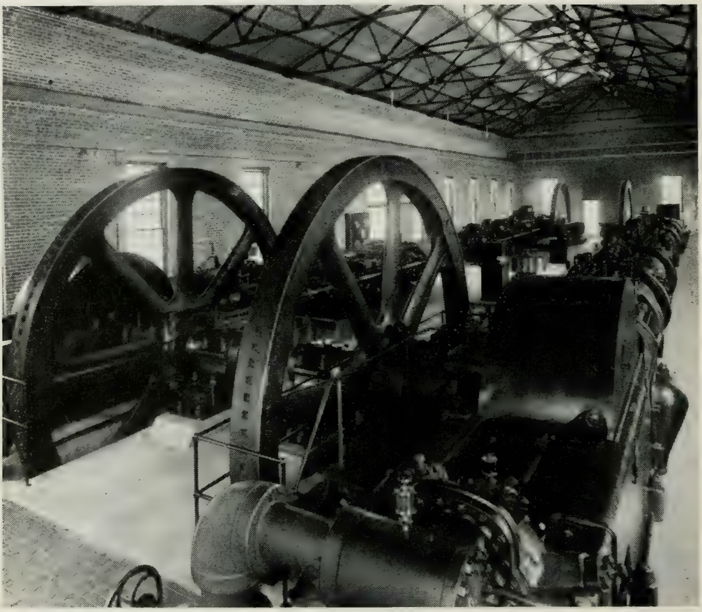


Fig. 121—BRADEN STATION, OKLAHOMA NATURAL GAS CO., KELLEYVILLE, OKLAHOMA

Four 650 h. p. Single Tandem Compressors.

Do not place a large capacity meter less than two miles ahead of a compressor, without providing an extra system of gas tanks or drips to absorb the vibration or throb of the piston.

Ample receiver or tank capacity should be provided on the high pressure line, located from 100 to 200 feet from the compressing plant, with a blow-off valve, so that the moisture and semi-solids carried by the gas, may be dropped in cooling, trapped and blown off, and thus prevented from passing into the line.

In case of dirty gas, it is also important to provide a tank or receiver upon the intake main near the compressing plant, to trap out sand and solids to prevent their entrance into the compression cylinders.

When the intake line is operated below atmospheric pressure a by-pass can be arranged to cut off the tank and blow it out.

A relief valve should always be placed on the compressor discharge between the cylinder and the first gate, to protect the compressor in case it is started up with the discharge gate closed.

Fig. 122—HAULING A COMPRESSOR BED FROM RAILROAD TO COMPRESSOR PLANT
One of the many incidental expenses incurred in supplying cities distant from the gas fields with Natural Gas

Fig. 123—EXTERIOR VIEW OF THE WAYNESBURG COMPRESSING STATION

Booster—In gas fields where the pressure has dropped down to ten or fifteen pounds and the market is within a reasonable distance, boosters can be installed in place of compressors. A booster consists of a high pressure blower with power. While it is not capable of greatly increasing the pressure, it will have large volume capacity. The outfit does not call for a very large investment, and is often worked with success, especially where the consumption does not exceed from 3,000,000 to 5,000,000 cu. ft. per day.

Boosters are often installed near gas fields to deliver the gas to a compressor station two or three miles away. This is a great assistance to the compressor station and also decreases the size of the compressor required.

Number of Compressor Stations, Horse Power, etc.—Throughout the United States and Canada there are over two hundred stations compressing natural gas for domestic use. The total horse power aggregates approximately 325,000. About 1,800,000 domestic consumers are dependent for their gas supply on these compressor installations.

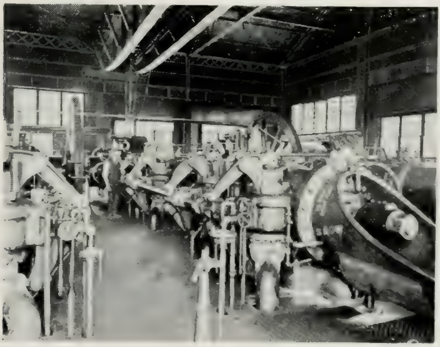


Fig. 124

PART EIGHT

Measurement of Flowing Gas in Pipe Lines

PITOT TUBE—ORIFICE METER
LARGE CAPACITY METER

Henri Pitot—Henri Pitot, a French Physicist and Engineer, was born in 1695, and died in 1771. It was probably sometime during the year 1750 that he invented the device for measuring the velocity in a stream by means of the velocity head which it will produce. In its simplest form it consists of a bent tube, the mouth of which is placed pointing upstream and measures the impact or dynamic pressure made by the flowing water. The water rises in the vertical part of the bent tube to a heighth above the surface of the flowing stream, and this height is equal to the velocity-head $V^2/2g$, so that the actual velocity v is in practice practically equal to $\sqrt{2gh}$. As constructed for use in streams, Pitot's apparatus consists of two tubes placed side by side with their submerged mouths at right angles so that when one is opposed to the current, the other stands normal to it.

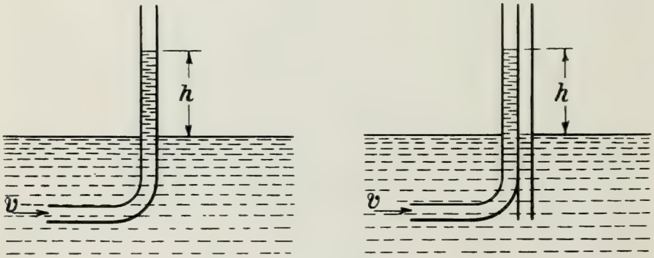


Fig. 125—THE FIRST PITOT TUBE USED IN MEASURING FLOWING STREAMS

Pitot Tube—From the foregoing invention was first devolved the method now commonly used, to measure the open flow of gas wells. But one tube is used with which to measure the dynamic flow of the gas, it not being necessary to measure the static or atmospheric pressure.

Later in 1904, Mr. B. C. Oliphant, of Buffalo, N. Y., perfected what is now known as the Oliphant Pitot Tube described in the following article:

MEASUREMENT OF NATURAL GAS WITH PITOT TUBES

B. C. Oliphant

At the time natural gas was first being introduced in the large cities, both for commercial and industrial purposes, the question came up as to how to measure the large quantities of gas at the city limits of the cities being supplied. This was for the following purposes: 1st: To know just what the daily consumption was, and to determine the maximum or peak loads, and at what hours they came. 2nd: To determine the amount of leakage, or loss in the city plants; or, in other words, to check up the domestic and commercial meters over a period of a month, or a year.

The Buffalo Natural Gas Fuel Co., of Buffalo, N. Y., was the first one to go into this question, and experiments entailing a great deal of expense, and covering a long period of time, were conducted in Buffalo.

At this time, little was known of the proportional meters, which had not then reached the perfection which they have to-day. They were then more on the type of the old boiler meters, and due to the large quantities of gas which they had to handle, and the heavy pressures under which the gas passed through the meters, they were unwieldy affairs. These meters were tested out against a large gas holder. Under constant conditions, for which they were set, both as

for rate of flow and pressure they gave very good results, but when the pressure was made to vary, and the rate of flow diminished or increased, the meter proved that it might run fast or slow. Consequently, after a great many tests of this kind had been made, the scheme of using the Pitot Tube Gauge, or more commonly known as the Pitot Meter, was decided upon.

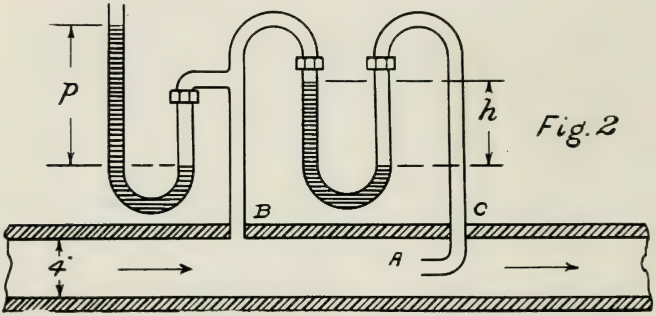


Fig. 126—THE FIRST PITOT TUBE USED IN MEASURING FLOWING GAS IN A PIPE LINE

The first Pitot Tubes used in the measurement of natural gas were rather crude affairs compared with the Pitot Tube of to-day. Figure 126 is a rough sketch of the Pitot Tube as first used for the measurement of natural gas

The principles of this tube, however, are identically the same as those used in the more refined tube of to-day. "A" was a piece of 3/8" iron pipe, "L" shaped and inserted in a 4" pipe so that the open end "A" came directly in the centre of the pipe. "B" was placed one foot distant from the point "C" and on the up-stream side. By means of the gas flowing against the open end "A," the static and dynamic pressures were transmitted to the "U" tube, and only the static pressure was transmitted from the point "B." In other words, the two static pressures were balanced, and the only thing then left was the dynamic pressure which caused the

water in the "U" tube to rise to the height "h." This "h" then is the height of water, or pressure which would produce the velocity "V" of the gas flowing in the pipe line. The static, or gauge pressure "p" was observed by means of a large "U" tube filled with mercury. The Pitot Tube was then calibrated and the co-efficient for it determined by passing gas through the Pitot Tube into a large gas holder under varying conditions of flow and pressure. Other tubes were then made by comparing them to these tubes, and as they proved successful after a good many years it was determined to make more refined tubes of various sizes, and again compare them with the gas holder, thus giving what is known as Standard Tubes to which all other tubes are compared, and their co-efficients determined. The following will describe the methods and various formulæ employed in determining their co-efficients.

Br = Atmospheric pressure pounds per square inch;

P_t = Gauge pressure, Pitot Tube, pounds per square inch;

P_H = Gauge pressure, Gas Holder, pounds per square inch;

h = Difference water level inches, Pitot Tube,

$Br + P_t$ = Absolute pressure. Pitot Tube, pounds per square inch,

$Br + P_H$ = Absolute pressure. Gas Holder, pounds per square inch,

L = Lift of holder in feet

V = Volume of holder in cu. feet for each foot rise—7238 cu. feet,

K = Volume passed by Pitot Tube in five minutes.

By using the Pitot Tube formula, we have:

$$K = C\sqrt{h(Br + p_t)}$$

Where C is the co-efficient to be determined.

For the holder, taking 14.4 pounds per square inch, as the average atmospheric pressure and four ounces as selling or buying pressure,—or 14.65 lbs. per sq. inch, we have:

$$K = 494.06 \times L(Br + P_H)$$

Hence:

$$C\sqrt{h(Br + P_t)} = 494.06 \times L\ (Br \times P_H)$$

or,

$$C = 494.06 \times L\ \frac{(Br \times P_H)}{\sqrt{h(Br + P_t)}}$$

The above "C" will be for five minutes run, or 1–12 the hourly co-efficient.

Under Buffalo conditions, the average yearly flowing and storage temperature of the gas was found to be 40° and 50° fahr., respectively. Hence the temperature of the flowing gas at the tube was carefully observed, as was also the temperature of the gas in the holder and the co-efficient "C" corrected by the following formula:

$$C_x = C\frac{T_o}{T_H}\sqrt{\frac{T_t}{T_f}}$$

Where,

C_x = Corrected co-efficient.

T_o = Absloute Standard temperature of stored gas (461+50) = 511° fahr.

T_H = Absolute Temperature of gas in holder.

T_f = Absolute Temperature of flowing gas (461+40)=501° fahr.

T_t = Absolute Temperature of flowing gas in tube.

In determining the co-efficient of each tube, the dynamic head (h) was made to vary from one to twenty-eight inches

and the pressure was also made to vary over a wide range, and as a result of over one hundred tests, the co-efficients for two, three, four and five-inch Standard Tubes were obtained. These co-efficients were corrected for four ounce selling or buying pressure; 0.644 Specific Gravity of gas; 40° fahr., flowing and 50° fahr. storage temperatures of gas. Having now Standard Pitot Tubes and either co-efficient determined, it is a simple matter to determine co-efficients for other tubes by comparing them to the Standard Tubes in the following manner:

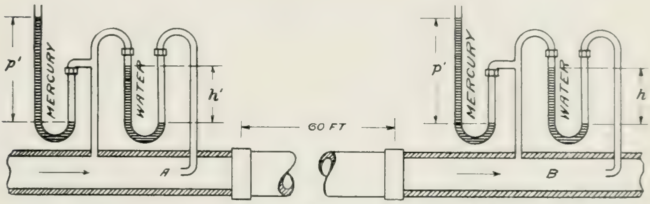


Fig. 127—TESTING ONE TUBE AGAINST A STANDARD TUBE TO DETERMINE THE CO-EFFICIENT FOR NEW TUBE

In Figure 127, suppose A to be the Standard Tube whose co-efficient C is known, and suppose B to be a Pitot Tube whose co-efficient C is to be determined. As A and B are in the same line of pipe and only separated by about sixty feet and have no leaks between them, the same amount of gas will pass through Pitot Tube B as through the Standard Pitot Tube A,

hence—$C' \sqrt{h'(p' + Br)} = C \sqrt{h(p + Br)}$

$$C' = C \frac{\sqrt{h(p + Br)}}{\sqrt{h'(p' + Br)}}$$

Where A and B are so close together, there is practically no difference in temperature, and consequently, no correction.

The co-efficient C' determined above, will be for standard conditions, viz:

40° fahr. = Flowing Temperature of Gas
50° fahr. = Storage Temperature of Gas
0.644 = Specific Gravity of Gas
Base = 4 Ounce selling or buying pressure

Assuming C' to have been established on the above conditions, and it is desired to change the co-efficient to suit new conditions as follows:—

Standard pressure and temperature basis, (Storage Values) P_s and T_s instead of P_o and T_o:

Gravity G_x instead of G_f and the flowing temperature T_x instead of T_f.

Let C_x be the correct co-efficient.

Then, for a change in Pressure Base from P_o to P_s

$$C_x = C' \frac{P_o}{P_s}$$

For change in Temperature Base from T_o to T_s

$$C_x = C' \frac{T_s}{T_o}$$

For change in Gravity Base from G_f to G_x

$$C_x = C' \sqrt{\frac{G_f}{G_x}}$$

Where the flowing temperature is T_x instead of T_f

$$C_x = C' \sqrt{\frac{T_f}{T_x}} \text{ i. e. correction factor } = \sqrt{\frac{T_s}{T_x}}$$

In this manner, a tube may be changed to meet any conditions, and, indeed, such has been done with very satisfactory results. We now have, after corrections have been made, the following formula for the quantity of natural gas (Q) per hour passing through a tube whose hourly co-efficient is C,

$$Q = C\sqrt{h(p+14.4)}$$

where h—difference in inches of the water level in the U gauge.

p = gauge pressure

14.4 = The average yearly atmospheric pressure in pounds per square inch for conditions where natural gas is usually sold.

From the expression $\sqrt{h(p+14.4)}$, it will be readily seen that a table can be compiled which makes the work of arriving at the quantity Q, a very simple matter.

In this manner, millions of cubic feet of natural gas per day are being bought and sold through these tubes. They are being used to determine pipe line leakage and losses. They are used to determine the efficiency of natural gas

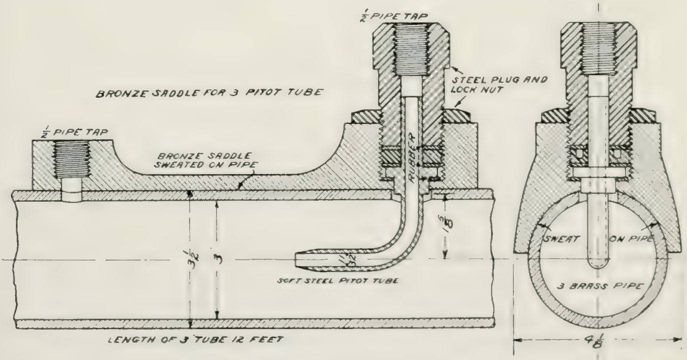


Fig. 128—SECTIONAL VIEW OF THE OLIPHANT PITOT TUBE
Showing Saddle, Tip and section of Brass Tube

compressors. They are used to test gas meters of all kinds under pressure, both in the shop and in the Field, and they are also used to determine the amount of gas a well will put into a line against different pressures.

The drawing on page 345 shows the arrangement of the Pitot Tube as used to-day.

Portable Pitot Tube—The ordinary commercial Pitot Tube should be used with caution, however, for in spite of its extreme simplicity it is a delicate instrument and should be handled as such. When used in ordinary pipe lines, the velocities encountered may give differential pressures so small that it is impossible to read them with accuracy and the interior surface of the pipe may be rough and uneven, a condition that seriously affects the result obtained with the instrument. The internal diameter of commercial pipe is not strictly uniform and is difficult to obtain with exactness, and as this factor enters into the Pitot Tube formula as the square of the value, any error in the measurement of the diameter is squared in its percentage effect upon the final result. A further difficulty is presented in the necessity of placing the tube in the cross section of the pipe at the point of average velocity, which point varies in the different sizes of pipe, and for different conditions of interior surface. A better plan is to place the tip in the center of the pipe and use the co-efficient obtained by actual calibration for each size of pipe. If this is done and care is taken to see that the interior of the pipe is free from sediment or dirt, and its diameter where the tip is inserted is accurately obtained, very satisfactory results may be obtained in the field with the Pitot Tube. In all cases, a free run of at least forty feet of pipe of the same size as that in which the tube is inserted must be installed on the inlet side of the tube, and ten feet on the outlet, and there must be no fittings or obstructions nearer to the tube than these distances.

The best use of the Pitot Tube is obtained where it is especially designed for permanent installation, and when properly built and installed it becomes a scientific instrument of high precision. It should be constructed of a carefully made steel tip having a hole about one-quarter inch in diameter, inserted in the exact center of a seamless drawn brass tube with interior surface highly polished and gauged to accurate and uniform size throughout its length. The tip should be mounted in a saddle in such a manner as to be capable of being removed with ease for cleaning, and of being reinserted so as to occupy exactly the same position as before removal. The size of the brass tube used is determined by the quantity of gas to be measured, and is so chosen as to produce velocities much higher than those encountered in the main pipe lines, in order to give a high differential or impact pressure reading, thus greatly increasing the accuracy of the instrument by diminishing the error of observation. Each tube must be calibrated against a standard tube and a co-efficient obtained, which, when multiplied into the square root of the product of the differential pressure and the static pressure (in absolute units), will give the flow in unit time.

These high precision tubes are usually installed in batteries of two or more, for obtaining measurements of a wide range of flows, and must have a sufficient run of pipe of the same size as the tube, both ahead and behind them, to avoid eddies and counter currents in the flow. The polished interior surface of the tube, and the high velocity of the gas prevent the formation of deposits and the tube co-efficient thus remains constant for a long period. Should any accident occur whereby the tube becomes dented or injured in any way, it is necessary to have it repaired and recalibrated to obtain a new co-efficient.

The Pitot Tube is usually used with water readings up to 30, or even 36 inches. Above this value the U gauge becomes cumbersome. It is not practical to use it with a differential

lower than one inch of water, as at this value an error of observation of 0.02 inches will produce an error in Q of one per cent. Its practical working range is therefore 6 to 1, i. e., it will give values within one per cent. of correct from maximum capacity down to one-sixth maximum. For very accurate work this range is usually cut down to about 4 to 1, corresponding to minimum water reading of about 2.25 inches. In other words, a tube with a capacity of 100,000 cu. ft. per hour at a certain pressure would have accuracy down to 25,000 cu. ft. per hour.

It also should be borne in mind that Pitot Tube observations must be made every fifteen minutes during the twenty-four hours. This requires the services of two men working twelve-hour shifts.

Orifice Meter—The heavy upkeep of the Pitot Tube as a measuring device for natural gas made its use limited, but from this invention the orifice meter was devised by John G. Pew and H. C. Cooper, of Pittsburgh, Pa., in 1911.

This type of meter is especially adapted for measuring high pressure gas in small or large volumes at the edge of the town or city or in the field at the wells.

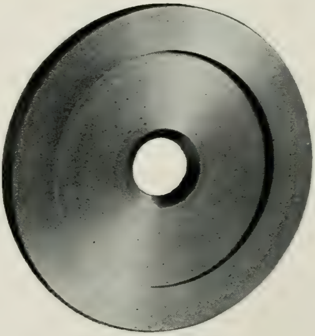


Fig. 129—THIN ORIFICE
Used in Orifice Meter Flange Fig. No. 130

The orifice meter consists of an orifice in a thin plate inserted in the pipe line, the differential pressure around it being obtained by means of an encased recording low pressure gauge or a specially constructed differential gauge, while the static pressure is obtained by an ordinary recording pressure gauge.

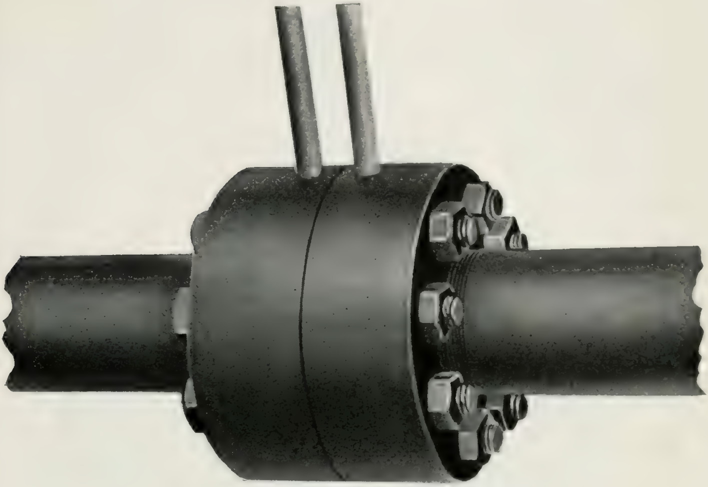


Fig. 130—ORIFICE METER FLANGE

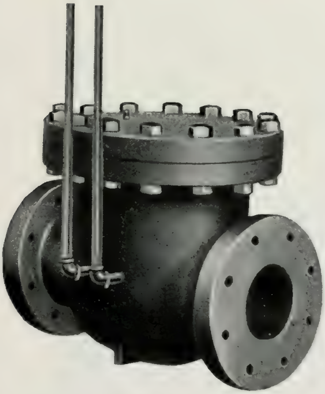


Fig. 131—ORIFICE METER CASTING

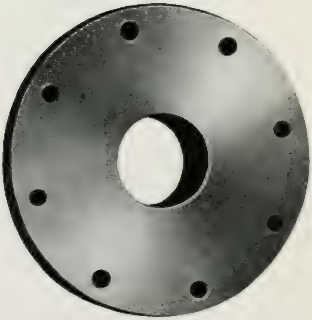


Fig. 132—JET ORIFICE
Used in Orifice Meter Casting
Fig. No. 131

The formula for computing flow by means of the orifice meter is identical with that for the Pitot Tube except that the co-efficient for an orifice of given size is smaller than that of a tube of the same size, due to the lower "efficiency," or co-efficient of flow.

If the true co-efficient of an orifice is known, it furnishes an accurate means of measuring gas.

Fig. 133—INSTALLATION OF TWO ENCASED TYPE OF ORIFICE METERS

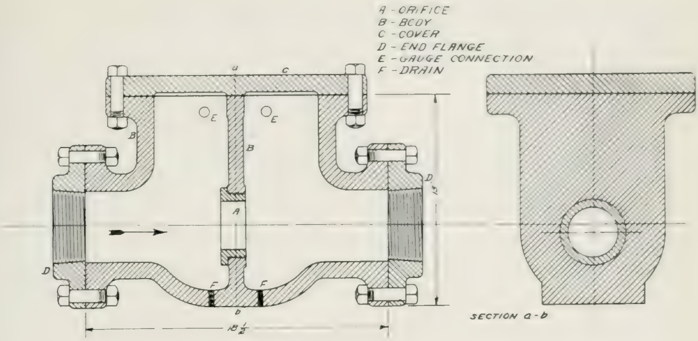


Fig. 134—SECTIONAL VIEW OF ONE TYPE OF ORIFICE METER

Orifices—Gas is being measured by many types of orifices developed by many experimenters with various methods of connecting the pressure pipes.

Among these should be mentioned the thin plate with the cylindrical hole in which the plates vary from 1-32″ to 1/8″ in thickness; plates of varying thickness from 1 1/4″ to 1/4″ drawn down by bevelling at various angles to a thin edge usually in the center or up-stream side of the plate; plates with cylindrical holes from 1″ to 2″ thick.

The orifice plates are made of various materials such as soft iron, coated with German silver to prevent corrosion; mild steel boiler plates; case-hardened or tempered steel.

The reason for the use of these various materials, is the theory as to the action of the gas on the disc. The plating or coating is based on the theory that the principal danger is change in area of the orifice by corrosion. The hardened steel is based on the theory that the principal danger is a change in area from scouring or sand-blasting of the hole. The mild steel plates are used on the assumption, that neither of the two effects mentioned above is a source of serious trouble, but that the important thing is to be able to machine the orifice to an exact micrometer dimension so

that the capacity can be determined by measurement of the orifice and the use of a pre-determined co-efficient, without individual calibrations for each disc; the principle being self-evident, that more accurate calibrations can be made for a determination for the purpose of establishing a standard for all meters than is possible in individual calibrations for each individual meter. Those advocating case-hardened orifices or orifices requiring individual calibration believe that corrosion and wear are more dangerous to accuracy than possible vagaries in individual calibrations.

Recording Differential Gauges—There are two types of recording differential gauges for use with the orifice meter, the encased and open type.

The former consists of a common recording differential gauge with chart graduated in inches of water pressure. Its maximum range of pressure is either sixty or one hundred inches of water. This gauge is encased within a heavy casting with two peep holes through the cover. The casting is slightly larger than the gauge, with a cover bolted on and is made to stand high pressure. A recording water pressure gauge is placed within the casting and connected through the casting with the high or up-stream side of the orifice flange or casting by a small sized pipe, either three-eights or one-half inch. Another small pipe connects the gauge casting with the low or down-stream side of the orifice flange or casting. The gas from the up-stream side of the orifice exerts a pressure upon the outside of the gauge spring and the gas from the down-stream side of the orifice exerts on the inside of the spring, a slightly lower pressure due to the friction of the gas passing through the orifice, and the gauge registers the difference in inches of water pressure.

TABLE SHOWING MAXIMUM AND MINIMUM CAPACITY PER 24 HOURS OF THE VARIOUS SIZES OF THIN PLATE ORIFICES AT DIFFERENT PRESSURES. USING A 60 INCH DIFFERENTIAL CHART.

Specific gravity of gas .644. Atmospheric pressure 14.4. Pressure base 4 oz.

Diameter of Orifice (For 4-inch flange)	Pressure Pounds per Square Inch							
	15 lb.	30 lb.	60 lb.	100 lb.	150 lb.	200 lb.	250 lb.	300 lb.
1/2″	14,400 64,500	18,000 79,000	23,000 102,000	28,000 127,000	34,000 152,000	39,000 174,000	43,000 193,000	47,000 211,000
3/4″	32,400 145,000	40,000 178,000	52,000 231,000	64,000 287,000	77,000 344,000	88,000 393,000	97,000 437,000	106,000 476,000
1″	58,000 259,000	71,000 318,000	92,000 412,000	114,000 511,000	137,000 613,000	156,000 700,000	174,000 777,000	189,000 847,000
1 1/2″	125,000 562,000	155,000 692,000	200,000 895,000	248,000 1,110,000	297,000 1,331,000	340,000 1,520,000	377,000 1,688,000	411,000 1,840,000
2″	232,000 1,040,000	285,000 1,278,000	370,000 1,655,000	458,000 2,052,000	550,000 2,459,000	628,000 2,809,000	697,000 3,119,000	760,000 3,404,000
2 1/2″	390,000 1,744,000	479,000 2,143,000	620,000 2,775,000	769,000 3,441,000	922,000 4,125,000	1,054,000 4,711,000	1,170,000 5,230,000	1,275,000 5,700,000
3″	621,000 2,779,000	764,000 3,416,000	988,000 4,420,000	1,226,000 5,481,000	1,470,000 6,570,000	1,678,000 7,503,000	1,864,000 8,336,000	2,032,000 9,087,000

TABLE SHOWING MAXIMUM AND MINIMUM CAPACITY—Continued

Diameter of Orifice (For 8-inch flange)	Pressure Pounds per Square Inch							
	15 lb.	30 lb.	60 lb.	100 lb.	150 lb.	200 lb.	250 lb.	300 lb.
2″	220,000 987,000	271,000 1,213,000	351,000 1,568,000	435,000 1,945,000	522,000 2,332,000	596,000 2,663,000	662,000 2,958,000	722,000 3,225,000
3″	495,000 2,211,000	607,000 2,714,000	786,000 3,518,000	975,000 4,360,000	1,169,000 5,003,000	1,335,000 5,972,000	1,483,000 6,632,000	1,617,000 7,232,000
3½″	682,000 3,052,000	838,000 3,750,000	1,085,000 4,855,000	1,346,000 6,020,000	1,614,000 7,217,000	1,843,000 8,242,000	2,046,000 9,153,000	2,232,000 9,981,000
4″	909,000 4,065,000	1,117,000 4,995,000	1,446,000 6,466,000	1,793,000 8,019,000	2,150,000 9,613,000	2,455,000 10,978,000	2,726,000 12,191,000	2,972,000 13,294,000
4½″	1,185,000 5,300,000	1,456,000 6,513,000	1,885,000 8,431,000	2,337,000 10,455,000	2,802,000 12,533,000	3,200,000 14,312,000	3,554,000 15,894,000	3,875,000 17,331,000
5½″	1,854,000 8,291,000	2,278,000 10,189,000	2,949,000 13,190,000	3,657,000 16,356,000	4,384,000 19,607,000	5,007,000 22,391,000	5,560,000 24,866,000	6,063,000 27,115,000
6½″	3,158,000 14,124,000	3,881,000 17,357,000	5,024,000 22,468,000	6,230,000 27,858,000	7,468,000 33,399,000	8,528,000 38,126,000	9,474,000 42,348,000	10,328,000 46,170,000

It requires several minutes to change the charts on this type of gauge; but there is no shaft working through a stuffing box, so that the slight friction found in the open type gauge is eliminated.

The other type of gauge is a special type in which the spring only is encased and surrounded by high pressure gas and the movement of the spring is transmitted to the marking arm on the chart by a small axle passing through a stuffing box.

All recording differential gauges are very sensitive and must be tested with a water column periodically.

Mercury Float Recording Differential Gauge—In this gauge the pressure acts directly upon a seal of mercury in a pot, with the float following the mercury level and transmitting to the marking arm on the chart, by means of a shaft and stuffing box, any variation in the differential pressure.

Fig. 135—Mercury Float Recording Differential and Static Pressure Gauge. This gauge carries two pen arms marking on one chart

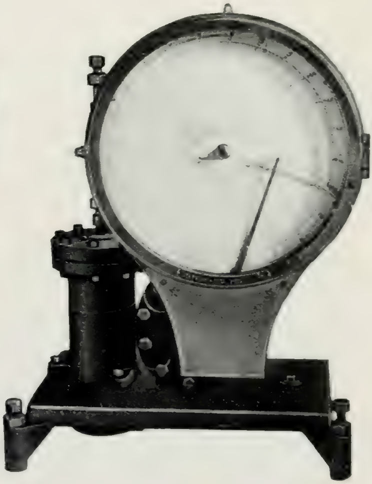


Fig. 136—Mercury Float Recording Differential Pressure Gauge

There are two advantages in this gauge, first, a sudden rise in the differential pressure, which might strain or injure the gauge, would blow the mercury seal without injury to the gauge. The mercury is put in the pot after the gauge is installed in the field and in event of the seal being blown the mercury pot can be refilled to the proper level or, till the marking arm on the chart rests at zero.

Second, the mercury float gauge will measure gas carrying a high percentage of sulphur without affecting the gauge.

With the spring recording gauge, if the differential pressure should rise suddenly, it would be liable to strain the gauge making it necessary to return it to the factory for repairs and test. Sulphur gas will corrode the spring, making it useless.

Static Pressure Recording Gauge for Orifice Meters—With the encased recording differential gauge it is necessary to use a separate static recording gauge.

With the open type the static pressure spring is incorporated within the differential gauge case, and two marking arms record both the static and differential pressures on one chart, one marking with red and the other with black ink.

Information Necessary in Ordering Orifice Meters—In ordering Orifice Meters always give the following information:

Estimate of the maximum volume per hour at the maximum pressure.

Estimate of the maximum volume per hour at the minimum pressure.

Estimate of the minimum volume per hour at the maximum pressure.

Estimate of the minimum volume per hour at the minimum pressure.

Specific Gravity of the gas.

Size of the pipe line.

Selling or buying base.

Average temperature of the gas.

The Specific Gravity of the gas should be taken periodically, as it is liable to change. As gas wells grow old their gravity has a tendency to become higher. Unless the true specific gravity of the gas is known and the co-efficient corrected for same, the Orifice Meter will not measure the gas accurately.

An orifice flange may be placed in any sized line by reducing or increasing the line at the orifice, so as to have at least twenty feet of pipe of the same size diameter as the flange on either side of the orifice.

While it is possible to install a four inch flange in an eight inch line and get accurate results, it is advisable to have the flange the same size as the line, thereby saving extra fittings.

When installing an orifice, always have a gate on either side and about twenty feet from the flange. This will allow the changing of the orifice with the least amount of gas loss.

Fig. 137 —MIDWAY FIELD, CALIF.

LARGE CAPACITY METER

Large Capacity Meter—Where the volume of gas or air to be measured exceeds 6,000 cubic feet per hour, or the pressure is above five pounds, the most practical and cheapest method of measurement is by a proportional or large capacity meter. Many gas companies use a large capacity meter to measure a volume of gas as small as 2,000 cubic feet per hour at a low pressure.

While it is true that in the early days of large volume, high pressure gas measurement the proportional meter bore a doubtful reputation, during recent years many improvements have been made in these instruments, and they have been brought to a high standard of efficiency and accuracy.

The large capacity meter is a most important instrument to the natural gas fraternity and without doubt there is less known about it by the actual caretaker than about any other piece of apparatus under his care. It is seldom taken into consideration that it is a hard-worked piece of machinery, receiving little care and attention. Many instances are known where large capacity meters were not even cleaned, although in constant use for a period of two years or longer. While as a rule it is not good policy to repair a meter in the field without subsequent testing, nevertheless there are a great many things that may happen to it which would only call for the tightening of a nut or screw, or replacing some part that would not affect the accuracy of the meter whatever.

The large capacity meter, like any other sensitive instrument, needs attention. It is often blamed for a great deal of inaccuracy that should be charged to the pipe line. If a meter is believed to be inaccurate, it should be very carefully tested by a competent meter man, and if any controversy exists it would be

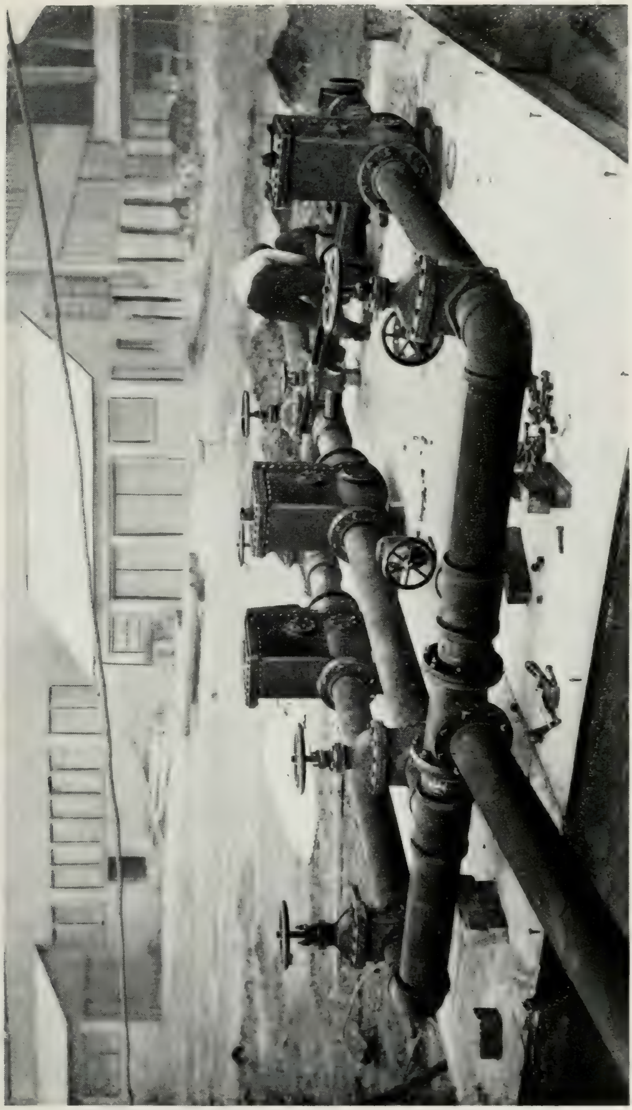


Fig. 138.—INSTALLING A BATTERY OF LARGE CAPACITY METERS AT A CEMENT PLANT NEAR DALLAS, TEX. *Building erected after meters are installed*

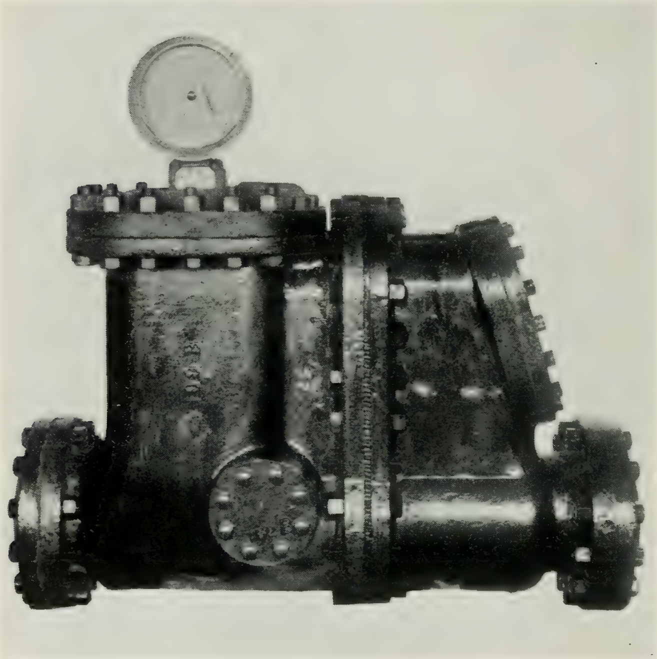


Fig. 139—500-LB. TEST LARGE CAPACITY METER
With Recording Volume and Pressure Gauge.

policy to have the meter tested once a month and all records of tests kept on file at the gas company's office. When a gas company, selling to another company in the field, decides to have a test made, it is no more than fair (whether a disagreement exists or not) that the other interested party should be asked to have a representative present during the test. The results of the test should not be kept secret but should be held as common property between the two companies interested. Secrecy in testing meters often breeds trouble and creates a great deal of unnecessary dissatisfaction.

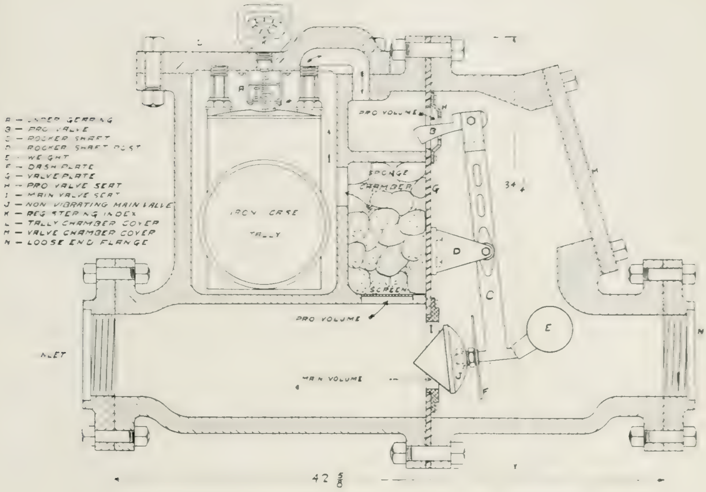


Fig. 140—SECTIONAL VIEW OF A LARGE CAPACITY METER

Measure gas at as low a pressure as possible. It is customary to measure gas on a four ounce basis unless otherwise specified in a preliminary agreement. A great many field companies purchase gas on an eight ounce basis. The slight advantage gained by this increased pressure is supposed to offset the small loss caused by the pipe line leakage.

A factory meter measuring gas at a low pressure will only measure accurately a volume of low-pressure gas up to its rated capacity in cubic feet, while a field or high-pressure meter will measure accurately a volume of low-pressure gas at a high pressure far in excess of the rated capacity of the meter, entirely dependent upon the pressure. For example, a 10,000 cubic foot per hour, large capacity dry meter will measure accurately as follows:

Meter Reading	Pressure Pounds per Square Inch	Multiplier	Actual Amount of Low Pressure Gas Measured
10,000	.25	1.0000	10,000
10,000	100.00	7.8088	78,088
10,000	200.00	14.6348	146,348

The above figures are given under the assumption that the meter is working up to its maximum capacity, or 10,000 cubic feet per hour meter reading.

To determine the proper-sized meter to measure any volume the following rule is followed:

Divide the volume of gas to be measured per hour by the multiplier or density at which the gas is to be measured and it will give the meter reading for which to select the proper sized meter.

Example:—If it is desired to measure 146,348 cubic feet of low pressure gas per hour at a pressure of 200 pounds — 146,348 ÷ 14.6348 = 10,000 cubic feet per hour meter reading.

Range of Accuracy of Large Capacity Meter—A large capacity meter is tested and corrected to within two per cent of accuracy within the limits of its capacity.

Accurate measurement cannot be expected below a certain minimum volume which will vary according to the rated capacity of the meter. From the writer's experience, a table is given below showing a reasonable minimum range of accuracy for meters of different types and rated capacities.

Capacity of Meter Cu. ft. per hour. (Meter Reading)	Minimum Range of accuracy Cu. ft. per hour (Meter Reading)
3,000	500
6,000	700
10,000	900
20,000	1,800
35,000	3,600
50,000	3,600
75,000	3,600
100,000	3,600
125,000	7,200
150,000	10,800

All sizes of the different makes are tested in the factory to smaller volumes than those given above but it is extremely difficult to retain this accuracy on such small volumes in an instrument that was designed for heavier duty both as to pressure and volume.

For volumes under 1,000 cubic feet per hour it is best to use a positive meter.

To expect any type or make of meter to measure a wide range of volumes—for example a 20,000 cubic feet per hour capacity meter to measure a minimum volume of 600 cubic feet per hour is unreasonable. It might be likened to a merchant weighing a pound of butter with a set of hay scales.

Where in the same pipe line it is necessary to measure large and small volumes of extremely wide range it is more reasonable to use two different size meters; a large size for the large volume and a smaller size for the small volume. By so doing very close accuracy can be obtained.

A large capacity meter given proper care and used within its rated capacity will prove to be a wonderfully accurate measuring instrument.

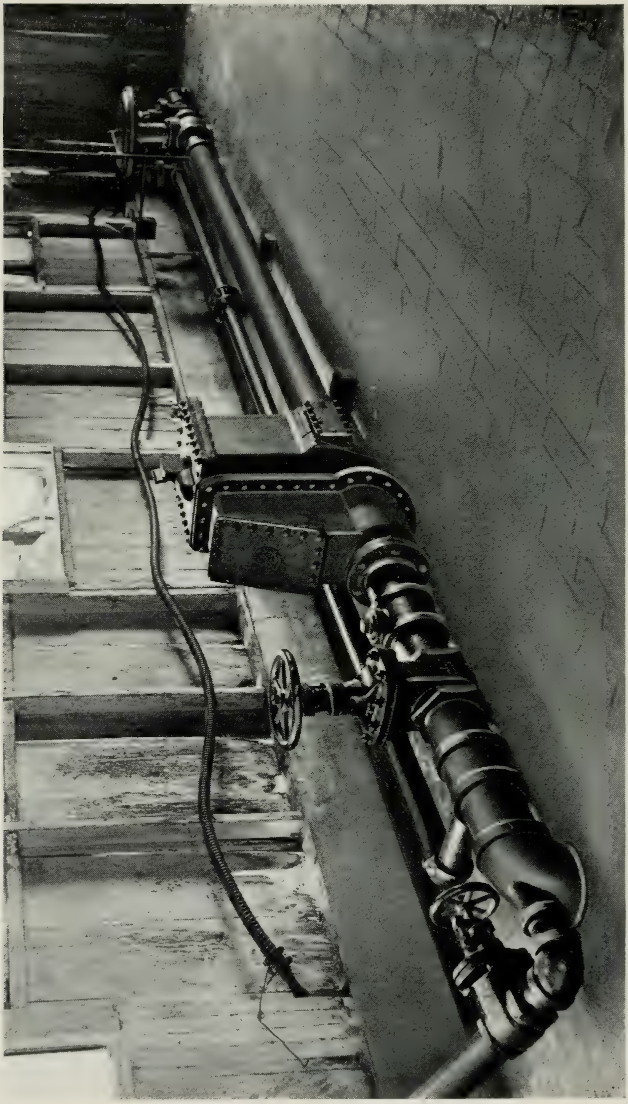


Fig. 141—6" Large Capacity Meter Setting showing Regulator at Little Rock, Ark. Note—Amount of pipe between Regulator and Meter, also Tee between outlet flange and outlet gate, for testing with funnel on foundation. Exhaust pipe from regulator safety valve is run through roof of building

Tables to Determine the Proper Size Meter, in Measuring Low and High Pressure Gas with the Large Capacity Dry Meter, where the Maximum Volume per 24 Hours Is Given at Four Ounces Pressure Above an Atmospheric Pressure of 14.4 Lb. per Square Inch.

Max. Volume per Hour Cu. Ft.	Max. Volume per 24 Hours Cu. Ft.	Capacity of Meters at Different Pressures In Cubic Feet per Hour								
		4 Oz.	25 Lb.	50 Lb.	75 Lb.	100 Lb.	150 Lb.	200 Lb.	300 Lb.	400 Lb.
6,000	100,000	6,000	3,000	3,000	3,000	*	*	*	*	*
10,000	250,000	10,000	6,000	3,000	3,000	3,000	*	*	*	*
20,000	500,000	20,000	10,000	6,000	6,000	3,000	3,000	3,000	*	*
41,000	1,000,000	50,000	20,000	10,000	10,000	6,000	6,000	3,000	3,000	3,000
62,000	1,500,000	75,000	20,000	20,000	10,000	10,000	10,000	6,000	3,000	3,000
83,000	2,000,000	100,000	35,000	20,000	20,000	10,000	10,000	10,000	6,000	3,000
104,000	2,500,000	100,000	35,000	20,000	20,000	20,000	10,000	10,000	6,000	6,000
125,000	3,000,000	125,000	50.000	35,000	20,000	20,000	20,000	10,000	10,000	6,000
146,000	3,500,000	150,000	50,000	35,000	35,000	20,000	20,000	20,000	10,000	6,000
166,000	4,000,000	†175,000	75,000	35,000	35,000	35,000	20,000	20,000	10,000	10,000
208,000	5,000,000	†200,000	75,000	50,000	35,000	35,000	20,000	20,000	10,000	10,000
250,000	6,000,000	†250,000	100,000	75,000	50,000	35,000	35,000	20,000	20,000	10,000
330,000	8,000,000	†325,000	125,000	75,000	75,000	50,000	35,000	35,000	20,000	20,000
416,000	10,000,000	†400,000	150,000	100,000	75,000	75,000	50,000	35,000	20,000	20,000
500,000	12,000,000	†500,000	†200,000	125,000	100,000	75,000	50,000	50,000	35,000	20,000
625,000	15,000,000	†600,000	†225,000	150,000	125,000	100,000	75,000	50,000	35,000	35,000
832,000	20,000,000	†825,000	†300,000	†200,000	150,000	125,000	75,000	75,000	50,000	35,000

*Use high pressure tally meters for these capacities. † Use two or more meters in battery form.

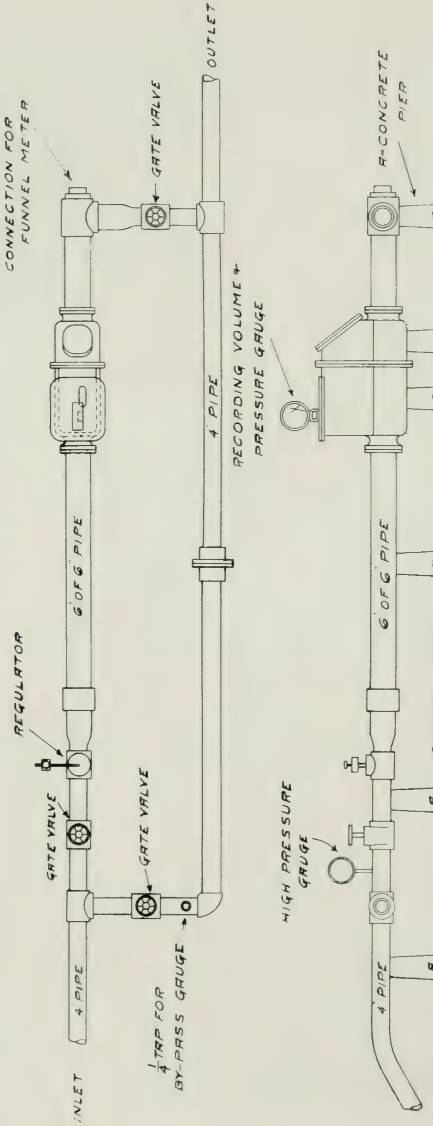


Fig. 142.—SETTING FOR SIX-INCH LARGE CAPACITY METER

Proving Large Capacity Meters Large capacity meters are proved in the factory for volume with air at four inches water pressure corrected to the barometer and thermometer readings at time of test. The proving instruments used are the standard flow meter, funnel meter, large prover and Oliphant Pitot Tube. The latter is used for high pressure proving. In field proving, an additional correction is made on the pressure for the difference between the specific gravity of the gas and the air (air being 1).

Pressure Testing of Large Capacity Meters—Hydraulic water pressure is used in testing large capacity meters for leaks, imperfections in castings and strength of metal. Following water test, air under high pressure is used.

Fig. 143
The "Burning Well" at Caney, Kans., (1909) after it was capped and shut in.

Fifty pound meters are tested up to seventy-five pounds. Two hundred pound meters are tested up to two hundred and fifty pounds. Five hundred pound meters are tested up to five hundred and fifty pounds.

Advantage should not be taken of the pressure test above the rated strength of the meter, as this additional test is made as a precautionary measure.

Over Capacity in Large Capacity Meters—All dry meters will work over capacity to a reasonable extent, especially the small sizes. For instance the 6,000 cubic feet per hour meter will measure accurately up to 7,200 cubic feet per hour. It is not good policy to take advantage of this over capacity constantly, but if used occasionally it will not injure the meter.

Invariably the differential above the rated capacity of the meter increases greatly out of proportion to the differential of the meter within capacity.

PRESSURES TO BE USED IN MEASURING AIR BAROMETRIC PRESSURES

Standard barometer..........29.2 inches Standard temperature...

Deg. Fahr.	Barometer Reading														
	28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0
	Pressure in Inches of Water														
30	4.23	4.24	4.26	4.27	4.29	4.30	4.32	4.33	4.35	4.36	4.38	4.39	4.40	4.42	4.44
31	4.22	4.24	4.25	4.27	4.28	4.29	4.31	4.32	4.34	4.35	4.37	4.38	4.39	4.41	4.43
32	4.21	4.23	4.24	4.26	4.27	4.29	4.30	4.32	4.33	4.34	4.36	4.37	4.39	4.40	4.42
33	4.20	4.22	4.23	4.25	4.26	4.28	4.29	4.31	4.32	4.34	4.35	4.37	4.38	4.39	4.41
34	4.20	4.21	4.22	4.24	4.25	4.27	4.28	4.30	4.31	4.33	4.34	4.36	4.37	4.39	4.40
35	4.19	4.20	4.22	4.23	4.25	4.26	4.27	4.29	4.30	4.32	4.33	4.35	4.36	4.38	4.39
36	4.18	4.19	4.21	4.23	4.24	4.25	4.27	4.28	4.30	4.31	4.32	4.34	4.35	4.37	4.38
37	4.17	4.18	4.20	4.21	4.23	4.24	4.26	4.27	4.29	4.30	4.32	4.33	4.34	4.36	4.37
38	4.16	4.17	4.19	4.21	4.22	4.23	4.25	4.26	4.28	4.29	4.31	4.32	4.34	4.35	4.37
39	4.15	4.17	4.18	4.20	4.21	4.23	4.24	4.25	4.27	4.28	4.30	4.31	4.33	4.34	4.36
40	4.14	4.15	4.17	4.19	4.20	4.22	4.23	4.25	4.26	4.28	4.29	4.30	4.32	4.33	4.35
41	4.14	4.15	4.17	4.18	4.19	4.21	4.22	4.24	4.25	4.27	4.28	4.29	4.31	4.32	4.34
42	4.13	4.14	4.16	4.17	4.19	4.20	4.22	4.23	4.24	4.26	4.27	4.29	4.30	4.32	4.33
43	4.12	4.12	4.15	4.16	4.18	4.19	4.21	4.22	4.24	4.25	4.26	4.28	4.29	4.31	4.32
44	4.11	4.13	4.14	4.16	4.17	4.18	4.20	4.21	4.23	4.24	4.26	4.27	4.28	4.30	4.31
45	4.10	4.12	4.13	4.15	4.16	4.18	4.19	4.20	4.22	4.23	4.25	4.26	4.28	4.29	4.30
46	4.10	4.11	4.12	4.14	4.15	4.17	4.18	4.20	4.21	4.23	4.24	4.25	4.27	4.28	4.30
47	4.09	4.10	4.12	4.13	4.14	4.16	4.17	4.19	4.20	4.22	4.23	4.24	4.26	4.27	4.29
48	4.08	4.09	4.11	4.12	4.14	4.15	4.17	4.18	4.19	4.21	4.22	4.24	4.25	4.27	4.28
49	4.07	4.09	4.10	4.11	4.13	4.14	4.16	4.17	4.19	4.20	4.21	4.23	4.24	4.26	4.27
50	4.06	4.08	4.09	4.11	4.12	4.13	4.15	4.16	4.18	4.19	4.20	4.22	4.23	4.25	4.26
51	4.06	4.07	4.08	4.10	4.11	4.13	4.14	4.15	4.17	4.18	4.20	4.21	4.23	4.24	4.25
52	4.05	4.06	4.08	4.09	4.10	4.12	4.13	4.15	4.16	4.18	4.19	4.20	4.22	4.23	4.25
53	4.04	4.05	4.07	4.08	4.10	4.11	4.12	4.14	4.15	4.17	4.18	4.20	4.21	4.22	4.24
54	4.03	4.05	4.06	4.07	4.09	4.10	4.12	4.13	4.14	4.16	4.17	4.19	4.20	4.21	4.22
55	4.02	4.04	4.05	4.07	4.08	4.09	4.11	4.12	4.14	4.15	4.17	4.18	4.19	4.21	4.22
56	4.02	4.03	4.04	4.06	4.07	4.09	4.10	4.11	4.13	4.14	4.16	4.17	4.19	4.20	4.21
57	4.01	4.02	4.04	4.05	4.06	4.08	4.09	4.11	4.12	4.13	4.15	4.16	4.18	4.19	4.20
58	4.00	4.01	4.03	4.04	4.06	4.07	4.09	4.10	4.11	4.13	4.14	4.15	4.17	4.18	4.20
59	4.00	4.01	4.02	4.04	4.05	4.06	4.08	4.09	4.10	4.12	4.13	4.15	4.16	4.17	4.19
60	3.99	4.01	4.02	4.03	4.04	4.06	4.07	4.08	4.10	4.12	4.13	4.14	4.16	4.17	4.18
61	3.98	4.00	4.01	4.02	4.04	4.06	4.07	4.08	4.10	4.11	4.12	4.14	4.15	4.16	4.17
62	3.97	3.99	4.00	4.02	4.03	4.04	4.06	4.07	4.08	4.10	4.11	4.13	4.14	4.15	4.16
63	3.97	3.98	3.99	4.00	4.02	4.04	4.05	4.06	4.08	4.09	4.11	4.12	4.14	4.15	4.16
64	3.96	3.97	3.99	4.00	4.01	4.03	4.04	4.06	4.07	4.09	4.10	4.11	4.12	4.14	4.15
65	3.95	3.96	3.98	3.99	4.01	4.02	4.04	4.05	4.06	4.08	4.09	4.10	4.12	4.13	4.15
66	3.94	3.96	3.97	3.99	4.00	4.01	4.03	4.04	4.05	4.07	4.08	4.09	4.10	4.11	4.13
67	3.93	3.95	3.96	3.98	3.99	4.00	4.02	4.03	4.05	4.07	4.08	4.09	4.10	4.11	4.12
68	3.93	3.94	3.96	3.97	3.98	4.00	4.01	4.03	4.04	4.05	4.07	4.08	4.09	4.11	4.12
69	3.92	3.93	3.95	3.96	3.98	3.99	4.00	4.02	4.03	4.05	4.06	4.07	4.09	4.10	4.11

THROUGH A FUNNEL METER AT DIFFERENT AND TEMPERATURES

. . . .70 deg. fahr. Standard pressure. . . . . .4 inches water

Deg. Fahr.	Barometer Reading														
	28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0
	Pressure in Inches of Water														
70	3.91	3.92	3.94	3.96	3.97	3.98	4.00	4.01	4.02	4.04	4.06	4.07	4.07	4.08	4.10
71	3.91	3.92	3.94	3.95	3.96	3.98	3.99	4.00	4.02	4.03	4.05	4.05	4.05	4.07	4.09
72	3.91	3.91	3.93	3.94	3.96	3.97	3.99	4.00	4.01	4.01	4.02	4.03	4.05	4.06	4.08
73	3.90	3.91	3.92	3.94	3.95	3.96	3.98	3.99	4.00	4.01	4.02	4.03	4.05	4.06	4.08
74	3.90	3.90	3.91	3.93	3.94	3.96	3.97	3.98	4.00	4.01	4.02	4.03	4.06	4.06	4.07
75	3.88	3.90	3.90	3.92	3.93	3.95	3.96	3.97	3.98	4.00	4.02	4.03	4.03	4.04	4.06
76	3.87	3.88	3.89	3.90	3.93	3.94	3.95	3.96	3.97	4.00	4.01	4.01	4.02	4.04	4.06
77	3.86	3.88	3.89	3.90	3.92	3.93	3.95	3.96	3.97	3.99	4.01	4.01	4.03	4.04	4.06
78	3.86	3.87	3.88	3.89	3.91	3.92	3.94	3.95	3.97	3.98	3.99	40.1	4.02	4.03	4.05
79	3.85	3.86	3.88	3.89	3.90	3.92	3.93	3.94	3.96	3.97	3.98	4.00	4.01	4.02	4.04
80	3.84	3.85	3.87	3.89	3.90	3.91	3.92	3.94	3.95	3.96	3.98	3.99	4.00	4.01	4.03
81	3.84	3.85	3.86	3.88	3.89	3.90	3.91	3.93	3.94	3.96	3.98	3.99	4.00	4.01	4.02
82	3.83	3.84	3.85	3.87	3.88	3.90	3.92	3.93	3.95	3.96	3.98	3.99	4.00	4.00	4.01
83	3.82	3.84	3.85	3.86	3.88	3.89	3.90	3.91	3.93	3.94	3.96	3.97	3.98	3.99	4.00
84	3.82	3.83	3.85	3.86	3.86	3.89	3.90	3.91	3.93	3.94	3.96	3.97	3.97	3.99	4.00
85	3.81	3.82	3.84	3.85	3.86	3.88	3.88	3.90	3.91	3.92	3.94	3.95	3.96	3.98	3.99
86	3.80	3.81	3.83	3.84	3.85	3.87	3.88	3.89	3.90	3.92	3.93	3.95	3.96	3.97	3.99
87	3.80	3.80	3.82	3.83	3.84	3.86	3.87	3.88	3.89	3.90	3.92	3.94	3.95	3.97	3.98
88	3.79	3.80	3.81	3.83	3.84	3.85	3.87	3.88	3.89	3.90	3.91	3.93	3.95	3.96	3.97
89	3.78	3.80	3.81	3.82	3.84	3.84	3.86	3.87	3.88	3.89	3.91	3.92	3.94	3.95	3.97
90	3.77	3.79	3.80	3.82	3.83	3.84	3.85	3.86	3.87	3.88	3.90	3.91	3.93	3.95	3.96
91	3.76	3.78	3.80	3.81	3.83	3.84	3.84	3.86	3.87	3.88	3.90	3.91	3.92	3.94	3.96
92	3.76	3.77	3.79	3.81	3.82	3.82	3.83	3.85	3.86	3.87	3.89	3.90	3.91	3.93	3.94
93	3.75	3.76	3.78	3.79	3.80	3.82	3.83	3.84	3.86	3.87	3.88	3.89	3.90	3.92	3.93
94	3.75	3.76	3.77	3.78	3.79	3.81	3.82	3.84	3.85	3.86	3.87	3.88	3.90	3.91	3.92
95	3.74	3.75	3.76	3.78	3.79	3.81	3.82	3.83	3.84	3.85	3.86	3.88	3.89	3.91	3.92
96	3.74	3.75	3.76	3.77	3.78	3.80	3.81	3.82	3.84	3.86	3.86	3.87	3.88	3.90	3.91
97	3.73	3.74	3.75	3.77	3.78	3.79	3.80	3.82	3.84	3.85	3.87	3.87	3.89	3.89	3.90
98	3.72	3.74	3.75	3.76	3.77	3.78	3.80	3.81	3.82	3.83	3.85	3.86	3.87	3.88	3.90
99	3.71	3.73	3.73	3.75	3.77	3.78	3.79	3.80	3.81	3.83	3.84	3.86	3.87	3.88	3.89
100	3.71	3.72	3.72	3.74	3.76	3.77	3.78	3.79	3.80	3.82	3.83	3.85	3.86	3.87	3.88
101	3.70	3.71	3.72	3.74	3.75	3.76	3.77	3.79	3.80	3.81	3.83	3.84	3.85	3.86	3.88
102	3.69	3.70	3.71	3.73	3.74	3.75	3.76	3.78	3.79	3.81	3.82	3.83	3.84	3.85	3.87
103	3.68	3.70	3.71	3.72	3.74	3.75	3.76	3.77	3.79	3.80	3.81	3.83	3.84	3.85	3.87
104	3.67	3.69	3.70	3.71	3.72	3.74	3.75	3.76	3.78	3.79	3.80	3.81	3.83	3.84	3.86
105	3.67	3.68	3.70	3.71	3.72	3.73	3.74	3.76	3.77	3.79	3.80	3.81	3.83	3.84	3.85
106	3.66	3.68	3.69	3.70	3.72	3.73	3.74	3.76	3.77	3.78	3.79	3.80	3.82	3.83	3.84
107	3.66	3.68	3.68	3.70	3.71	3.72	3.73	3.75	3.76	3.78	3.79	3.80	3.81	3.83	3.84
108	3.65	3.67	3.68	3.69	3.70	3.72	3.73	3.74	3.75	3.77	3.78	3.79	3.80	3.82	3.83

Fig. 144—LOW PRESSURE GAUGE
Used in proving Large Capacity Meters. Can be used as a Differential Gauge, also for proving Domestic Meters

Table Giving Percentages Fast (+) and Slow (−) with Correcting Factors to be Used in Testing Large Capacity Meters with the Funnel Meter. All Figures Given on the Basis of an 1½″ Orifice Passing One Cubic Foot Per Second at a Four Inch Water Pressure Corrected for Barometer and Thermometer Changes and for Specific Gravity of Gas Used.

Fast Meters			Slow Meters		
Time Required by Meter to Register 100 Cu. Ft. in Seconds	Per Cent. Fast (Funnel Meter being Standard)	Correcting Factor. Deduct Meter Reading PerCent.	Time Required by Meter to Register 100 Cu. Ft. in Seconds	Per Cent. Slow Funnel Meter being Standard	Correcting Factor. Add to Meter Reading Per Cent.
100	O. K.	none	100	O. K.	none
99	1 +	1	101	.9—	1
98	2 +	2	102	1.9—	2
97	3 +	3	103	2.9—	3
96	4.1+	4	104	3.8—	4
95	5.2+	5	105	4.7—	5
94	6.3+	6	106	5.6—	6
93	7.5+	7	107	6.5—	7
92	8.6+	8	108	7.4—	8
91	9.8+	9	109	8.2—	9
90	11.1+	10	110	9. —	10
89	12.3+	11	111	9.9—	11
88	13.6+	12	112	10.7—	12
87	14.9+	13	113	11.5—	13
86	16.2+	14	114	12.2—	14
85	17.6+	15	115	13. —	15
84	19. +	16	116	13.7	16
83	20.4+	17	117	14.5	17
82	21.9+	18	118	15.2	18
81	23.4+	19	119	15.9	19
80	25. +	20	120	16.6	20
79	26.5+	21	121	17.3	21
78	28.1+	22	122	18. —	22
77	29.8+	23	123	18.6—	23
76	31.5+	24	124	19.3—	24
75	33.3+	25	125	20. —	25
74	35.1+	26	126	20.6—	26
73	36.9+	27	127	21.2—	27
72	38.8+	28	128	21.8—	28

Example:—If a meter passes 100 cubic feet in 80 seconds the meter is 25 per cent. fast on a basis of the funnel being standard but the correcting factor being 20, to correct meter reading, deduct 20 per cent.

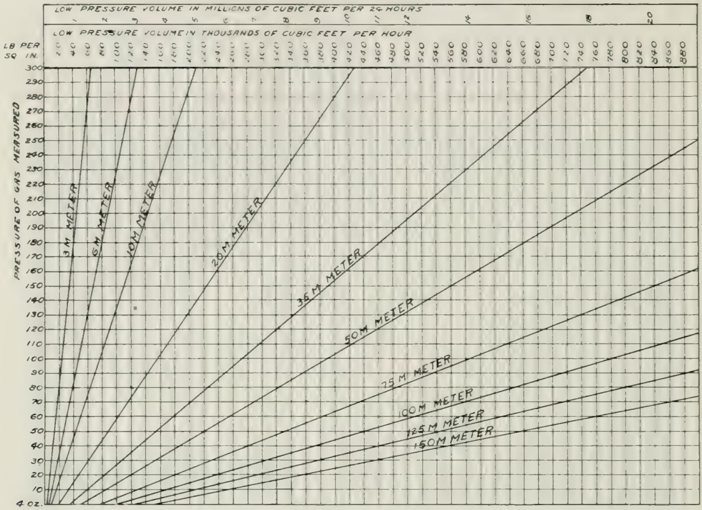


Fig. 145—CHART TO DETERMINE THE VOLUME OF LOW PRESSURE GAS OR AIR

A Large Capacity Dry Meter will measure at different high pressures per hour and per day

Installation—It is essential to use the proper amount of pipe on the inlet of the meter as designated in the directions accompanying the meter. For instance, in the case of an 8-inch meter, at least eight feet or more of 8-inch pipe should be used into the inlet flange. The meters are tested under these conditions in the factory and if the directions are not followed (as by use of 4-inch pipe directly into an 8-inch meter, or by placing an ell, gate, or regulator within less than eight feet from the inlet flange of an 8-inch meter) the tendency would be to create counter currents or eddies and cause the meter to run slow.

All large capacity meters should be set absolutely level on a solid foundation, concrete being the most desirable. In measuring gas in the field under high pressure in cold weather, the very best results are obtained by using a system

of heating without bringing the fire in too close proximity to the meter location in the interior of the building. This can be done by using 6- or 8-inch pipe or casing, building your torch fire ten or twelve feet away from the building, and constructing your flue and chimney from the fire directly through the building to the further end, then through the roof. That portion of pipe between the fire and the building, with the exception of directly at the location of fire, can be banked over with dirt, thereby preventing radiation of the heat until after the pipe enters the building. This method merely conducts the burnt gases and heat through the 6- or 8-inch pipe or casing into the building and through the roof, thereby having the same effect as steam, but without any danger of explosion.

Cleaning—The question is often asked, "How often shall we clean our meter?" This is a hard question to answer for the very reason that there are no two conditions found to be alike in the gas that passes through the meter. It is better to clean the meter too often than not often enough. One can judge by the condition the meter is found to be in at each cleaning.

By-Pass—It is considered objectionable by the majority of gas people to use a by-pass around the meter on account of the liability of leakages in the gate, thereby causing loss of measurement. Where meters are in use twenty-four hours a day (such as at glass factories and cement plants), and there is no possibility of shutting the gas off to make a test or repair to the large capacity meter, a by-pass is very essential unless a duplicate meter is used. The method of employing two meters, one in case of emergency, is seldom used, due to the heavy cost.

In the cases above mentioned the by-pass method can be employed without any loss whatever by the use of double gates and two pieces of pipe between the gates, with an expansion sleeve that can readily be detached after the test

or repair of meter. This leaves the by-pass broken and the gates can be plugged except when the by-pass is actually needed to allow the repair or test of the large capacity meter.

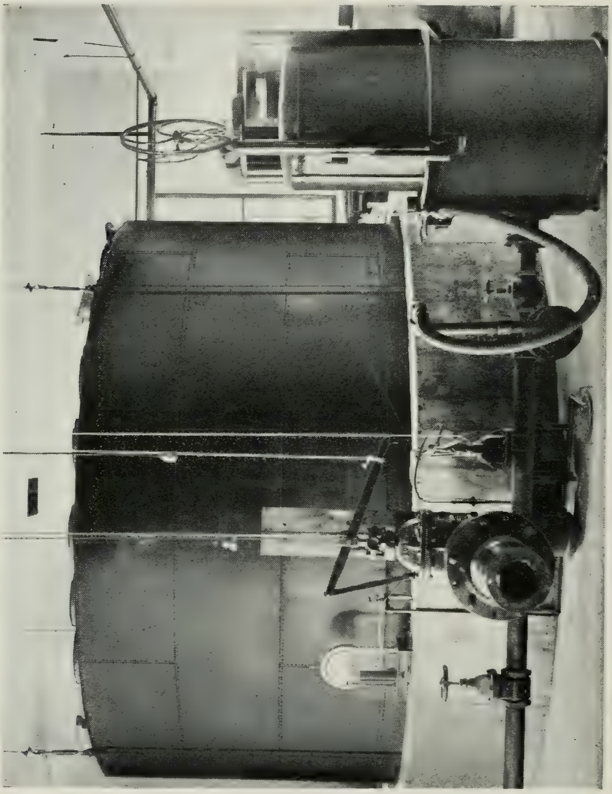


Fig. 146—LARGE CAPACITY PROVER FOR PROVING LARGE CAPACITY METERS, ORIFICES AND FUNNEL METERS

Turning Gas Into a Meter—While this may seem a simple subject, it is one of the most important instructions that can be given in the care of large capacity meters, especially in measuring high pressure gas.

Proper Sized Meter to Install Where Gas is Used to Generate Power Either in a Gas Engine or Under Steam Boilers.

Horse-power of Engine or Boilers	Capacity of Meter In Cu. Ft. per Hour		Horsepower of Engine or Boilers	Capacity of Meter In Cu. Ft. per Hour	
	In Gas Engine	Under Steam Boiler		In Gas Engine	Under Steam Boiler
10	500	800	150	3,000	10,000
15	500	1,500	200	6,000	20,000
20	800	1,500	300	6,000	20,000
25	800	3,000	400	10,000	35,000
35	1,500	3,000	500	10,000	35,000
50	1,500	6,000	600	10,000	50,000
75	3,000	6,000	800	20,000	50,000
100	3,000	10,000	1000	20,000	75,000

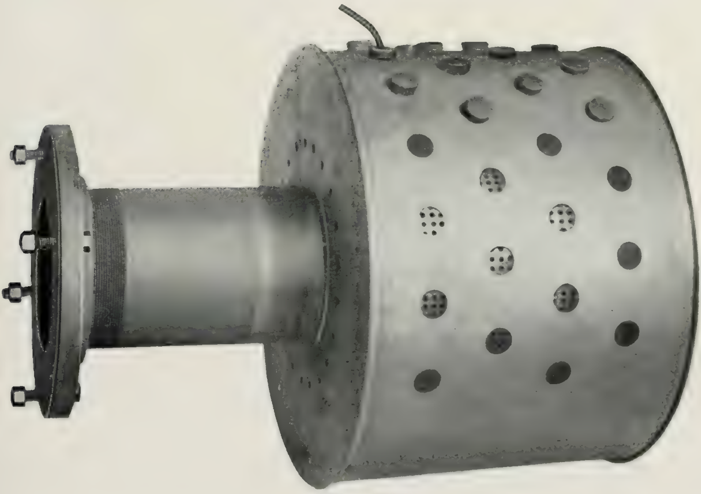


Fig. 147—FLOWOMETER FOR PROVING LARGE CAPACITY METERS IN THE FACTORY

Gas should be turned into the inlet first, **very slowly,** and when pressure in the meter equals the pressure in the line ahead of the meter, open outlet gate **very slowly.**

Turn gas into a field meter with the same precaution you would use in starting an automobile. By that it is meant—start on low gear, advance to second then after car is under way throw the gears into high speed. It is just as harmful to turn high pressure gas into a meter suddenly as it is to start an automobile on high gear or speed.

Condensation—All natural gas direct from the well carries more or less aqueous vapor.

Condensation in pipe lines, regulators and large capacity meters is caused by the difference of temperature of the gas and air. If the gas is warmer than the air the condensation will be on the interior of the pipe, regulator or meter; and if the gas is colder than the air, the condensation will be on the exterior. This condensation is commonly called sweating, being the moisture condensed from the atmosphere surrounding the pipe.

A gas torch placed on a gas line directly back of a drip will cause condensation of aqueous vapor in the drip where the condensed vapor is taken care of and greatly protects the meter or regulator if located ahead of and near the drip.

Drain Cocks—All meters should be installed with drain cocks on the inlet and outlet bowls to keep the meter absolutely dry. The fact that the gas in the well is dry is no guide to go by, for the reason that the gas may carry aqueous vapor which might find conditions en route from well to the meter causing it to condense into free water.

Lighting Measuring Stations—Where possible in installing a meter or regulator station, equip the house with one or two electric light bulbs with long wiring. Use wire cage over bulb. Place switch on outside of building or on some adjacent post or tree. Lightning arresters should be used.

Large Capacity Meter Gaskets—For 50 lb. and 200 lb. meters use soft cardboard about $\frac{1}{16}$-inch thick. Apply white lead on both sides of gasket.

For 500 lb. meters use asbestos board $\frac{3}{32}$-inch thick. Dampen before using. Apply coating of asphaltum on both sides of gasket after dampening.

To Read a Large Capacity Meter—In reading a meter the small or 100-foot dial should not be considered. Each subdivision in the circle represents one-tenth of the figures placed above the circle. In other words, on the 10,000 dial, if the hand points between 7 and 8, the figure the hand has just passed (which would be 7) indicates that over 7,000 cubic feet have passed. The 1000-foot dial is only taken into consideration when the hand points between 5 and 0, in which case it is counted as 1,000. In the foregoing case, if the hand on the 10,000-foot dial was close to 8 and the hand in the 1000-foot dial pointed at 8 or 9, the reading of the 10,000-foot dial would be 8,000. Each dial above the 10,000-foot dial is read the same as the 10,000-foot dial above described.

In reading the dial no attention should be paid to the wording "one per cent." or "two per cent." printed on the face of the dial. The wording is intended for use when ordering new clock or tally, and has no bearing on the meter reading.

Field Testing—During the past few years testing in the field with the funnel meter has become very common. No doubt there are objections to this method, but on the other hand there are advantages gained that cannot be obtained by shipping the meter to the factory for repairs and test. For instance, the natural jarring and knocking about that a meter receives en route from the lease location to the factory, may cause a great deal of the dirt collected on the valves to be jarred off, preventing the owner from obtaining a true test of what it was doing while in actual service in the field. It is also true that a large capacity meter in the

field can be tested with the funnel meter and repaired under average circumstances in a period of a few hours, or not to exceed two or three days. The old method generally kept the meter out of service for a period of from two to six weeks while being tested and repaired at the factory.

The error generally allowed in the field is 3 per cent. fast or slow, while the factory is confined to a 2 per cent. error either fast or slow.

Funnel Meter—While it is true that the funnel meter is a simple instrument, yet in order to obtain reliable results with it, it is very essential that the operator should be experienced in the use of the instrument and at the same time have a thorough knowledge of how to repair and correct the meter being tested. The proper place to gain this experience is at the factory. The most successful combination to make a large capacity meter expert is the actual experience in the field with experience of large capacity meter testing derived in the factory.

Great care should be used not only in handling but in storing the funnel meter when not in use. The edge of the different orifices should be kept perfectly dry. Rusting of

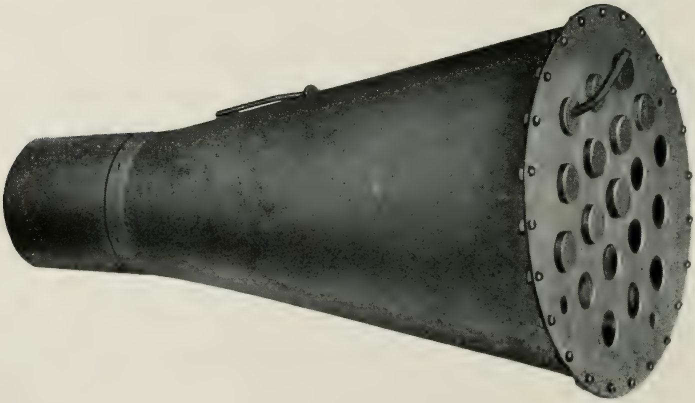


Fig. 148—FUNNEL METER WITH DETACHABLE HEAD

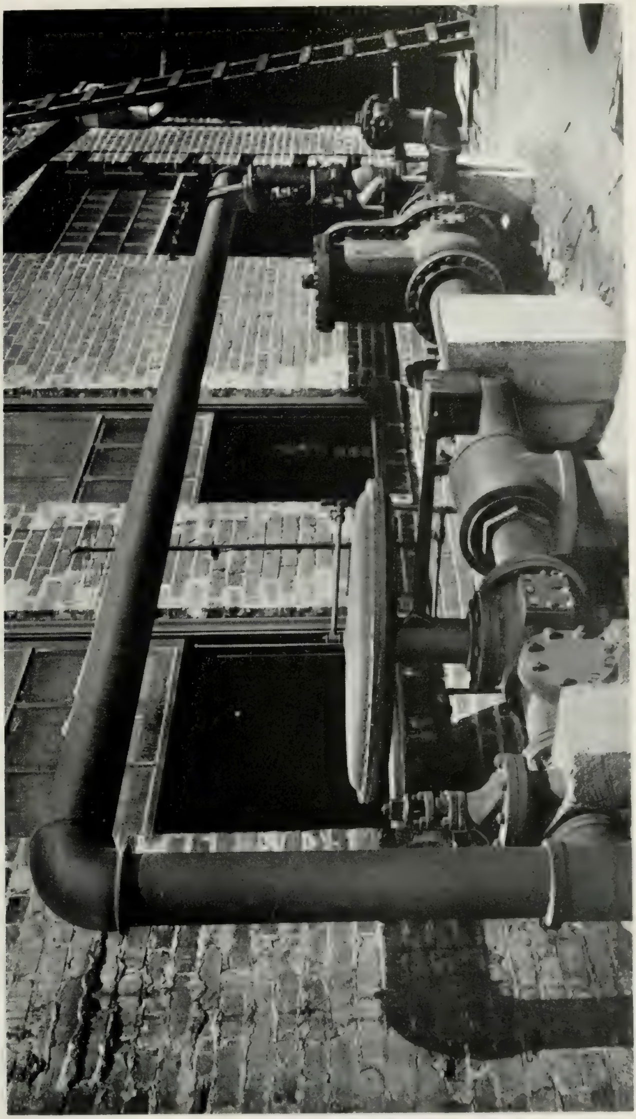


Fig. 149 INSTALLATION SHOWING OVERHEAD BY-PASS AND DRIP JUST AHEAD OF LOW PRESSURE REGULATOR, AT SHREVEPORT, LA.

the edges of the orifices will create inaccuracy in testing, and should this occur the funnel meter should be repaired and re-tested at the factory. In case the head—carrying the orifices—becomes dented, it is also necessary to have the funnel meter re-tested.

Large Capacity Meter for Measuring Compressed Air—This meter is a displacement meter and gives meter readings on clock or dial in compressed air figures. The capacity of the meter has reference to the meter reading.

If it is desired to reduce meter reading or compressed air figures to free air figures, use the multiplier tables for various pressures on page 391.

If the pressure is variable, a volume and pressure gauge is essential, the same as in measurement of high pressure gas. This records the pressure variations, together with the number of thousands of cubic feet of air passing through the meter at the recorded pressure, from which is computed the corresponding quantity of free air. The gauge will also show the peak and minimum loads during the twenty-four hour period. Gauges are furnished with either twenty-four hour or seven-day clocks.

Fig. 150—TESTING A LARGE CAPACITY METER IN THE FIELD

Do not set a meter near a compressor unless plenty of pipe area is furnished or tanks are installed between the meter and the compressor to eliminate the vibration or throb of the piston. Large capacity meters will stand a reasonable amount but not an excess of vibration.

Table to Determine the Proper Sized Meter, to be Used in Measuring Air, from Atmospheric Pressure up to 120 Pounds to the Square Inch, with a Large Capacity Meter, where the Maximum Volume per Minute of Free Air is Given.

Maximum Volume Free Air per Minute Cubic Feet	Capacity of Meters at Different Pressures In Cubic Feet per Hour				
	Atmospheric Pressure	30-Lb.	60-Lb.	90-Lb.	120-Lb.
50	3,000	3,000	*	*	*
100	6,000	3,000	3,000	*	*
200	10,000	6,000	3,000	3,000	*
300	20,000	6,000	6,000	3,000	3,000
400	35,000	10,000	6,000	6,000	3,000
500	35,000	10,000	6,000	6,000	6,000
600	35,000	20,000	10,000	6,000	6,000
800	50,000	20,000	10,000	10,000	6,000
1,000	75,000	20,000	20,000	10,000	10,000
2,000	125,000	50,000	35,000	20,000	20,000
2,500	†275,000	50,000	35,000	35,000	20,000

*Use tally meters encased to stand high pressure.
† For this volume use battery of meters.

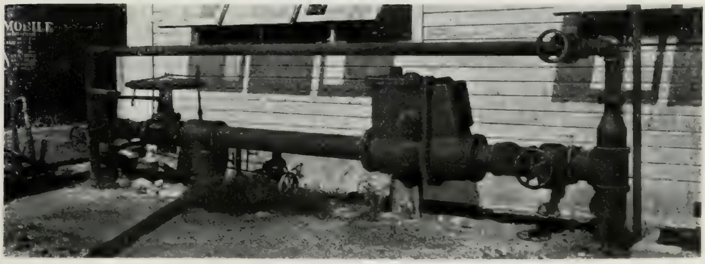


Fig. No. 151

Recording Gauge—Where gas is measured at a greater pressure than four ounces, a recording gauge is necessary to determine the pressure throughout the 24 hours so that the multiplier for the average pressure can be applied to the meter reading to obtain the actual amount of gas passed.

The recording gauge should be set on the meter itself and if it is a 24-hour gauge, the chart should be taken off daily and the day's reading, together with the previous day's reading, written on the back of the chart.

Before setting a recording gauge on a large capacity meter, see that the marking arm rests at zero.

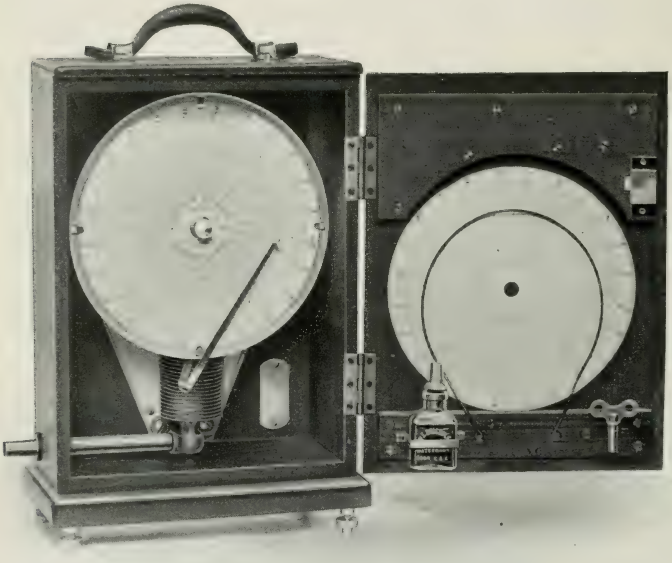


Fig. 152—RECORDING PRESSURE GAUGE IN CARRYING CASE

It is very essential to have recording pressure gauges that are used in connection with large capacity meters tested, as an error of ten pounds would amount to from 6 to 8 per cent. in the actual gas passed through the meter at 125 lb. pressure. At higher pressures the actual error would increase accordingly.

Volume and Pressure Recording Gauge—(Adapted for use on the Large Capacity Meters in measuring gas or compressed air.)—In measuring gas or compressed air, it is always desirable to determine the pressure of each 10,000 cubic foot volume passing through the meter. This enables the attendant to obtain the correct multiplier from which he calculates the actual amount of gas or air passing through the meter. In addition to recording the continuous pressure, this gauge is equipped with a volume marker so constructed that—by making an additional mark or dash on the margin of the circular chart—it indicates each 10,000 foot volume passed.

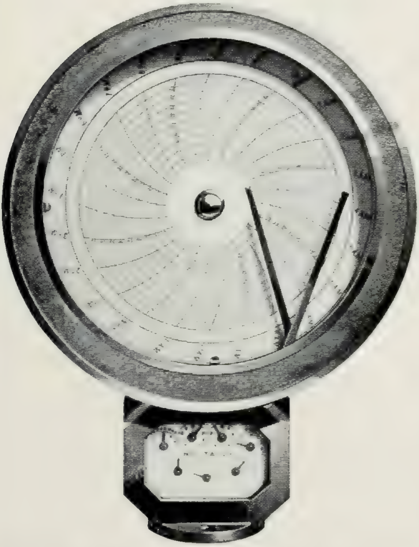


Fig. 153—Volume and Pressure Recording Gauge for use on Large Capacity Meters

There is another advantage in the use of the volume and pressure recording gauge, for if the line should break ahead of the meter, the gauge chart would show, not only the time

of the break, but also the number of 10,000 cubic foot volumes that had passed through the meter after the accident.

These gauges are equipped with either 1000, 10,000 or 100,000 cubic foot volume marking arms.

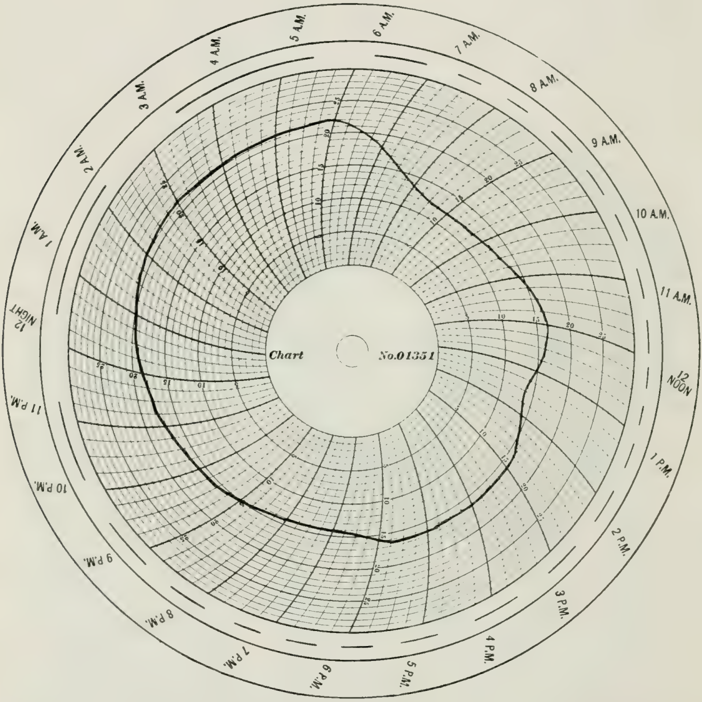


Fig. 154—A Recording Volume and Pressure Gauge Chart. Each dash, in space adjoining pressure graduations, indicates a 10,000 cu. foot volume has passed the meter.

PART NINE

Density Of Gases

Robert Boyle—Robert Boyle was an English natural philosopher, the seventh son and the fourteenth child of Richard Boyle, the great Earl of Cork. He was born at Lismore Castle, province of Munster, Ireland, January 25, 1627.

After three years at Eton he went abroad to travel with a French tutor. Returning to England in 1642 he found his father had died and left him estates at Dorsetshire and in Ireland. From that time on he gave his life to study.

Reading, in 1657, of Otto von Guericke's air pump, he set himself, with the assistance of Robert Hooke, to devise improvements in its construction. The pneumatic engine being finished in 1659, he began a series of experiments on the properties of air. An account of the work he did with this instrument was published in 1660 under the title "New Experiments Physico-Mechanical Touching the Spring of Air and Its Effects."

Among the critics of the views put forward in the book was a Jesuit, Franciscus Linue; and it was while answering his objections that Boyle enunciated the law that the "volume of gas varies inversely as the pressure." This law among English-speaking people, is called after his name; though on the continent it is attributed to E. Mariotte, who did not publish it till 1676.

Robert Boyle died December 30, 1691, at the house of his sister in Pall Mall, London.

Edmond Mariotte—The French physicist, Edmond Mariotte, was born in 1620 at Dijon, where he spent most of his life. He was one of the first members of the Academy of Science, founded in Paris in 1666. He died in Paris, May 12, 1684.

He wrote many essays between 1676 and 1679 bearing on physical subjects, such as motion of fluids, freezing water, and the barometer.

In his second essay, written about 1676, is the statement of the law that the "volume varies inversely as the pressure," which, though very generally called by his name, had been discovered by Robert Boyle in 1660.

Jacques Alexander Cesar Charles—Jacques Alexander Cesar Charles was a French mathematician and physicist, born in Beaugency, Loiret, November 12, 1746. He was the first to employ hydrogen for the inflation of balloons, and in about 1787 he anticipated Gay Lussac's law of dilation of gases with heat, which, on that account, is sometimes known by his name.

He died in Paris, April 7, 1823.

Boyle's and Mariotte's Law—In a perfect gas the volume is inversely proportional to the pressure to which the gas is subjected, or, what is the same thing, the product of the pressure and the volume of a given quantity of gas remains constant

Charles' Law—The volume of a given mass of any gas under constant pressure, increases from the freezing point by constant fraction of its volume at zero. In other words, gases expand $\frac{1}{273}$ of their volume at 0 deg. C. for each deg. of C. rise of temperature, and $\frac{1}{492}$ of their volume at 32 deg. fahr. for each deg. fahr. rise of temperature.

Expansion or Contraction of Natural Gas Due to Change in Temperature—All perfect gases expand or contract $\frac{1}{492}$

or 0.00203 of their volume at 32 deg. fahr. for an increase or decrease, respectively, of each deg. fahr. of temperature. Consequently if the temperature should fall 492 deg. below freezing temperature, or 460 deg. below zero, fahr., the volume of gas would contract to nothing. This point, namely, 460 deg. fahr., is called the absolute zero of temperature, and the absolute temperature of any gas is its temperature above freezing plus 460 deg. Thus 60 deg. standard temperature corresponds to 60 + 460 = 520 deg. absolute temperature.

Low Pressure Basis—The "Rock Pressure" of gas wells varies according to the depth of the well and the length of time the well has been drilled; likewise the pressure of the flowing gas in pipe lines, meters, regulators, and gates is extremely variable, and on account of this variation in pressure, it was found necessary to establish some basis on which to sell and buy natural gas.

Some years ago Mr. F. H. Oliphant, at that time of the United States Geological Survey, considered as a basis of natural gas measurement a pressure of 14.65 pounds per square inch absolute, and a temperature of 60 degrees fahr., and since then it has become customary for natural gas men to refer their gas measurements to this basis. A pressure of 14.65 pounds per square inch is 4 ounces above the assumed atmospheric pressure of 14.4 pounds per square inch, the latter being the average at about the elevation of the Great Lakes, which elevation was considered fairly representing that of most gas fields.

Density Changes in Gas Volumes—At 4-ounce pressure a cubic foot of gas is made up of a certain number of atoms. In order to increase the pressure in a cubic foot of gas confined into a like space, it is necessary to force into that space more gas or more atoms of gas. If a sufficient amount of gas is forced into the confined space, originally

holding a cubic foot of gas at 4-ounce pressure, to create 15 pounds pressure, there will then be twice as much gas, or twice as many atoms of gas confined in the same space

To illustrate, take a cylinder of proper diameter to contain one cubic foot of space for each foot in length fitted with a tight plunger.

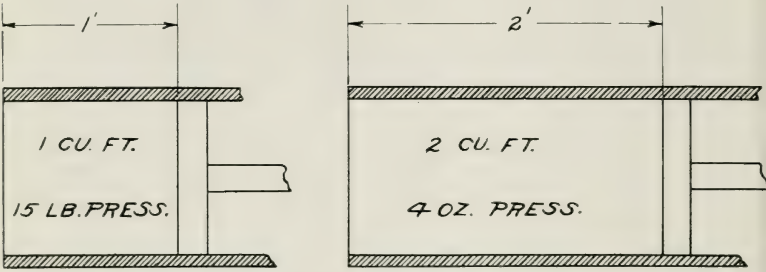


Fig. 155—NOTE—Pressures shown in Cuts are Gauge Pressures

If the plunger in the cylinder is placed at the one-foot mark and enough gas forced into the space to create a pressure of fifteen pounds, it could be said that the cylinder contained one cubic foot of 15-pound gas. Then if the plunger is withdrawn until it rests at the two-foot mark the gas will expand and the pressure will drop to four ounces and the actual volume contained in the space will be two cubic feet. In other words, by multiplying the cubic contents in the first cylinder by 2 it will give the actual amount of 4-ounce gas in cubic feet.

As all gas meters in the factory are tested and corrected to a low pressure basis, measuring gas by displacement, they may be compared to the cylinder with the plunger as illustrated above. In measuring gas in the meter, the diaphragms contain just so much space. If the pressure of the gas confined in each quantity or volume of gas measured by the diaphragms filling and discharging is four ounces, then the meter reading needs no correction; but each time the meter diaphragm fills and discharges a volume of gas at a higher

pressure than four ounces, the meter reading must be corrected by applying a multiplier, to reduce the volume of gas measured to a four-ounce basis; and the higher the pressure the greater will be the density of the gas and the greater the number of atoms contained in each cubic foot of space.

The multipliers for density are based on Boyle's law written in 1660, that the "volume of a gas varies inversely as the pressure."

While the four ounce basis is generally accepted when no other pressure basis is stated in a buying and selling agreement, some other basis can be used and very often is used, particularly when gas is bought or sold in large volumes in the field.

Formula for Determining the Quantity of Natural Gas When Measured Above Normal Pressure—In which

$$Q=q\frac{p+h}{h+.25}$$

Q = cubic feet required.
q = cubic feet shown by the meter.
p = gauge pressure in pounds.
h = atmospheric pressure of 14.4 pounds.
0.25 = 4-ounce pressure reduced to pounds.

By substituting the known values in the above it becomes

$$Q=q\frac{p+14.4}{14.65}$$

For Example:—Suppose the meter or q reads 1,000 cubic feet and the pressure p shows $32\frac{1}{2}$ pounds to the square inch, required to find the quantity of gas at a pressure of four ounces. Then

$$Q=1{,}000\frac{32.5+14.4}{14.65}=3.2013\times 1000=3{,}201.3$$

The result is therefore 3201.3 cubic feet at the standard pressure of four ounces to the square inch.

In the following pages will be found a set of multiplying tables for gas measured at 4 ounce pressure base. In compiling the multipliers, atmospheric pressure (which does not show on the gauge) at 14.4 pounds is taken, same being the average atmospheric pressure in the natural gas fields, and temperature of 60 deg. fahr. Usually no correction is made for change in temperature as 60 degrees fahr. represents an average temperature throughout the year.

Fig. 156

Multipliers for Reducing Gas Volumes or Meter Readings to a Pressure Base of 4 Ounces Above Atmospheric Pressure.

Gauge Pressure Inches of Mercury	Multiplier or Density	Gauge Pressure Lb. per Sq. In.	Multiplier or Density	Gauge Pressure Lb. per Sq. In.	Multiplier or Density
–25	.14535	7	1.46075	28	2.89419
–24	.17885	7½	1.49488	28½	2.92832
–23	.21236	8	1.52901	29	2.96245
–22	.24586	8½	1.56313	29½	2.99658
–21	.27936	9	1.59726		
–20	.31287	9½	1.63139	30	3.03071
–19	.34637			30½	3.06484
–18	.37987	10	1.66552	31	3.09879
–17	.41338	10½	1.69965	31½	3.13310
–16	.44688	11	1.73378	32	3.16723
		11½	1.76791	32½	3.20136
–15	.48038	12	1.80204	33	3.23549
–14	.51389	12½	1.83617	33½	3.26962
–13	.54739	13	1.87030	34	3.30375
–12	.58090	13½	1.90443	34½	3.33788
–11	.61440	14	1.93856		
–10	.64790	14½	1.97269	35	3.37201
– 9	.68141			35½	3.40614
– 8	.71491	15	2.00682	36	3.44027
– 7	.74841	15½	2.04095	36½	3.47440
– 6	.78191	16	2.07508	37	3.50853
		16½	2.10921	37½	3.54266
– 5	.81542	17	2.14334	38	3.57679
– 4	.84892	17½	2.17747	38½	3.61092
– 3	.88242	18	2.21160	39	3.64505
– 2	.91593	18½	2.24573	39½	3.67918
– 1	.94943	19	2.27986		
Atmos.	.98293	19½	2.31399	40	3.71331
				40½	3.74744
Lb. per Sq. In.		20	2.34812	41	3.78156
		20½	2.38225	41½	3.81569
0¼	1.00000	21	2.41638	42	3.84982
0½	1.01706	21½	2.45051	42½	3.88395
1	1.05119	22	2.48464	43	3.91808
1½	1.08532	22½	2.51877	43½	3.95221
2	1.11945	23	2.55290	44	3.98634
2½	1.15358	23½	2.58703	44½	4.02047
3	1.18771	24	2.62116		
3½	1.22184	24½	2.65528	45	4.05460
4	1.25597			45½	4.08873
4½	1.29010	25	2.68941	46	4.12286
		25½	2.72354	46½	4.15699
5	1.32423	26	2.75767	47	4.19112
5½	1.35836	26½	2.79180	47½	4.22525
6	1.39249	27	2.82593	48	4.25938
6½	1.42662	27½	2.86006	48½	4.29351

– Means "Vacuum" or minus pressure.

4-Ounce Multipliers—(*Continued*)

Gauge Pressure Lb. per Sq. In.	Multiplier or Density	Gauge Pressure Lb. per Sq. In.	Multiplier or Density	Gauge Pressure Lb. per Sq. In.	Multiplier or Density
49	4.32764	70	5.76109	91	7.19453
49½	4.36177	70½	5.79522	91½	7.22866
		71	5.82935	92	7.26279
50	4.39590	71½	5.86348	92½	7.29692
50½	4.43003	72	5.89761	93	7.33105
51	4.46416	72½	5.93174	93½	7.36518
51½	4.49829	73	5.96587	94	7.39931
52	4.53242	73½	6.00000	94½	7.43344
52½	4.56655	74	6.03412		
53	4.60068	74½	6.06825	95	7.46757
53½	4.63481			95½	7.50170
54	4.66894	75	6.10238	96	7.53583
54½	4.70307	75½	6.13651	96½	7.56996
		76	6.17064	97	7.60409
55	4.73720	76½	6.20477	97½	7.63822
55½	4.77133	77	6.23890	98	7.67235
56	4.80546	77½	6.27303	98½	7.70648
56½	4.83959	78	6.30716	99	7.74061
57	4.87372	78½	6.34129	99½	7.77474
57½	4.90784	79	6.37542		
58	4.94197	79½	6.40955	100	7.80887
58½	4.97610			101	7.87713
59	5.01023	80	6.44368	102	7.94539
59½	5.04436	80½	6.47781	103	8.01365
		81	6.51194	104	8.08191
60	5.07849	81½	6.54607	105	8.15107
60½	5.11262	82	6.58020	106	8.21843
61	5.14675	82½	6.61433	107	8.28668
61½	5.18088	83	6.64846	108	8.35494
62	5.21501	83½	6.68259	109	8.42320
62½	5.24914	84	6.71672		
63	5.28327	84½	6.75085	110	8.49146
63½	5.31740			111	8.55972
64	5.35153	85	6.78498	112	8.62798
64½	5.38566	85½	6.81911	113	8.69624
		86	6.85324	114	8.76450
65	5.41979	86½	6.88737	115	8.83276
65½	5.45392	87	6.92150	116	8.90102
66	5.48805	87½	6.95563	117	8.96928
66½	5.52218	88	6.98976	118	9.03754
67	5.55631	88½	7.02389	119	9.10580
67½	5.59044	89	7.05802		
68	5.62457	89½	7.09215	120	9.17406
68½	5.65870			121	9.24232
69	5.69283	90	7.12627	122	9.31058
69½	5.72696	90½	7.16040	123	9.37883

4-Ounce Multipliers—(*Continued*)

Gauge Pressure Lb. per Sq. In.	Multiplier or Density	Gauge Pressure Lb. per Sq. In.	Multiplier or Density	Gauge Pressure Lb. per Sq. In.	Multiplier or Density
124	9.44709	166	12.31392	208	15.18088
125	9.51535	167	12.38225	209	15.24914
126	9.58361	168	12.45051		
127	9.65187	169	12.51877	210	15.31740
128	9.72013			211	15.38566
129	9.78839	170	12.58703	212	15.45392
		171	12.65529	213	15.52218
130	9.85665	172	12.72354	214	15.59044
131	9.92491	173	12.79180	215	15.65870
132	9.99317	174	12.86006	216	15.72696
133	10.06143	175	12.92832	217	15.79522
134	10.12969	176	12.99658	218	15.86348
135	10.19795	177	13.06484	219	15.93174
136	10.26621	178	13.13310		
137	10.33447	179	13.20136	220	16.00000
138	10.40273			221	16.06825
139	10.47098	180	13.26962	222	16.13651
		181	13.33788	223	16.20477
140	10.53924	182	13.40614	224	16.27303
141	10.60750	183	13.47440	225	16.34129
142	10.67576	184	13.54266	226	16.40955
143	10.74402	185	13.61092	227	16.47781
144	10.81228	186	13.67918	228	16.54607
145	10.88054	187	13.74744	229	16.61433
146	10.94880	188	13.81569		
147	11.01706	189	13.88395	230	16.68259
148	11.08532			231	16.75085
149	11.15358	190	13.95221	232	16.81911
		191	14.02047	233	16.88737
150	11.22184	192	14.08873	234	16.95563
151	11.29010	193	14.15699	235	17.02389
152	11.35836	194	14.22525	236	17.09215
153	11.42662	195	14.29351	237	17.16040
154	11.49488	196	14.36177	238	17.22866
155	11.56313	197	14.43003	239	17.29692
156	11.63139	198	14.49829		
157	11.69965	199	14.56655	240	17.36518
158	11.76791			241	17.43344
159	11.83617	200	14.63481	242	17.50170
		201	14.70307	243	17.56996
160	11.90443	202	14.77133	244	17.63822
161	11.97269	203	14.83959	245	17.70648
162	12.04095	204	14.90784	246	17.77474
163	12.10921	205	14.97610	247	17.84300
164	12.17747	206	15.04436	248	17.91126
165	12.24573	207	15.11262	249	17.97952

4-Ounce Multipliers—(*Continued*)

Gauge Pressure Lb. per Sq. In.	Multiplier or Density	Gauge Pressure Lb. per Sq. In.	Multiplier or Density	Gauge Pressure Lb. per Sq. In.	Multiplier or Density
250	18.04778	292	20.91467	334	23.78156
251	18.11604	293	20.98293	335	23.84982
252	18.18430	294	21.05119	336	23.91808
253	18.25255	295	21.11945	337	23.98634
254	18.32081	296	21.18771	338	24.05460
255	18.38907	297	21.25597	339	24.12286
256	18.45733	298	21.32423		
257	18.52559	299	21.39249	340	24.19112
258	18.59385			341	24.25938
259	18.66211	300	21.46075	342	24.32764
		301	21.52901	343	24.39590
260	18.73037	302	21.59726	344	24.46416
261	18.79863	303	21.66552	345	24.53242
262	18.86689	304	21.73378	346	24.60068
263	18.93515	305	21.80204	347	24.66894
264	19.00341	306	21.87030	348	24.73720
265	19.07167	307	21.93856	349	24.80546
266	19.13993	308	22.00682		
267	19.20819	309	22.07508	350	24.87371
268	19.27645			351	24.94197
269	19.34470	310	22.14334	352	25.01023
		311	22.21160	353	25.07849
270	19.41296	312	22.27986	354	25.14675
271	19.48122	313	22.34812	355	25.21501
272	19.54948	314	22.41638	356	25.28327
273	19.61774	315	22.48464	357	25.35153
274	19.68600	316	22.55290	358	25.41979
275	19.75426	317	22.62116	359	25.48805
276	19.82252	318	22.68941		
277	19.89078	319	22.75767	360	25.55631
278	19.95904			361	25.62457
279	20.02730	320	22.82593	362	25.69283
		321	22.89419	363	25.76109
280	20.09556	322	22.96245	364	25.82935
281	20.16382	323	23.03071	365	25.89761
282	20.23208	324	23.09897	366	25.96587
283	20.30034	325	23.16723	367	26.03412
284	20.36860	326	23.23549	368	26.10238
285	20.43685	327	23.30375	369	26.17064
286	20.50511	328	23.37201		
287	20.57337	329	23.44027	370	26.23890
288	20.64163			371	26.30716
289	20.70989	330	23.50853	372	26.37542
		331	23.57679	373	26.44368
290	20.77815	332	23.64505	374	26.51194
291	20.84641	333	23.71331	375	26.58020

4-Ounce Multipliers—(*Continued*)

Gauge Pressure Lb. per Sq. In.	Multiplier or Density	Gauge Pressure Lb. per Sq. In.	Multiplier or Density	Gauge Pressure Lb. per Sq. In.	Multiplier or Density
376	26.64846	418	29.51535	460	32.38225
377	26.71672	419	29.58361	461	32.45051
378	26.78498			462	32.51877
379	26.85324	420	29.65187	463	32.58703
		421	29.72013	464	32.65528
380	26.92150	422	29.78839	465	32.72354
381	26.98976	423	29.85665	466	32.79180
382	27.05802	424	29.92491	467	32.86006
383	27.12627	425	29.99317	468	32.92832
384	27.19453	426	30.06143	469	32.99658
385	27.26279	427	30.12969		
386	27.33105	428	30.19795	470	33.06484
387	27.39931	429	30.26621	471	33.13310
388	27.46757			472	33.20136
389	27.53583	430	30.33447	473	33.26962
		431	30.40273	474	33.33788
390	27.60409	432	30.47098	475	33.40614
391	27.67235	433	30.53924	476	33.47440
392	27.74061	434	30.60750	477	33.54266
393	27.80887	435	30.67576	478	33.61092
394	27.87713	436	30.74402	479	33.67918
395	27.94539	437	30.81228		
396	28.01365	438	30.88054	480	33.74743
397	28.08191	439	30.94880	481	33.81569
398	28.15017			482	33.88395
399	28.21842	440	31.01706	483	33.95221
		441	31.08532	484	34.02047
400	28.28668	442	31.15358	485	34.08873
401	28.35494	443	31.22184	486	34.15699
402	28.42320	444	31.29010	487	34.22525
403	28.49146	445	31.35836	488	34.29351
404	28.55972	446	31.42662	489	34.36177
405	28.62798	447	31.49488		
406	28.69624	448	31.56313	490	34.43003
407	28.76450	449	31.63139	491	34.49829
408	28.83276			492	34.56655
409	28.90102	450	31.69965	493	34.63481
		451	31.76791	494	34.70307
410	28.96928	452	31.83617	495	34.77133
411	29.03754	453	31.90443	496	34.83959
412	29.10580	454	31.97269	497	34.90784
413	29.17406	455	32.04095	498	34.97610
414	29.24232	456	32.10921	499	35.04436
415	29.31057	457	32.17747		
416	29.37883	458	32.24573		
417	29.44709	459	32.31399	500	35.11262

For tables of multipliers of other bases see "Measurement of Gases Where Density Changes," by the author.

PART TEN

Regulation of Gas

REGULATORS: HIGH, INTERMEDIATE AND LOW—REGULATOR DIAPHRAGM—REGULATORS AND PLAIN END PIPE—INSTALLING—REGULATOR HOUSE—CARE OF REGULATORS—HEATING—REGULATOR BY-PASS—GRINDING VALVES.

Regulators—A gas regulator is practically a reducing valve or set of balanced valves automatically controlling and reducing, by throttling, the pressure of the gas entering an intermediate or low pressure main or line. The regulator is one of the most vital parts in a gas line system, and unless working perfectly will cause a great deal of trouble and loss. Too much attention cannot be paid to the care of the regulator.

As usually constructed, regulators, when working within their range, will maintain a nearly constant pressure in the outlet main. If an attempt is made to reduce the pressure of the gas through more than one hundred pounds, trouble is liable to occur, through freezing.

The outlet pressure of a regulator is controlled by weights on the lever arm connected with the diaphragm and valve stem.

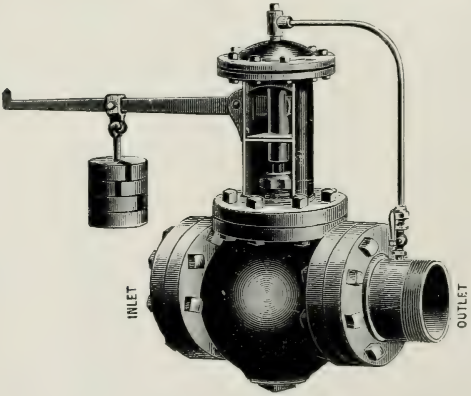


Fig. 157—HIGH PRESSURE OR REDUCING REGULATOR

High Pressure Regulators—A high pressure regulator is constructed with a small diaphragm and a small set of valves to enable it to take care of 500 to 600 pounds safely, and when especially ordered will take care of pressures of 800 to 1000 pounds. The work of a high pressure regulator is to reduce the pressure from a high to an intermediate pressure.

Intermediate Pressure Regulators—The work of an intermediate regulator is to reduce the pressure from 50 to 100 pounds down to 15 or 20 pounds, so that the low pressure regulator will control the gas in a more sensitive manner without too great a reduction. The intermediate pressure regulator is not very commonly used, but when used, it greatly improves the work of both the high and the low pressure regulators. It gives a more sensitive and far safer service.

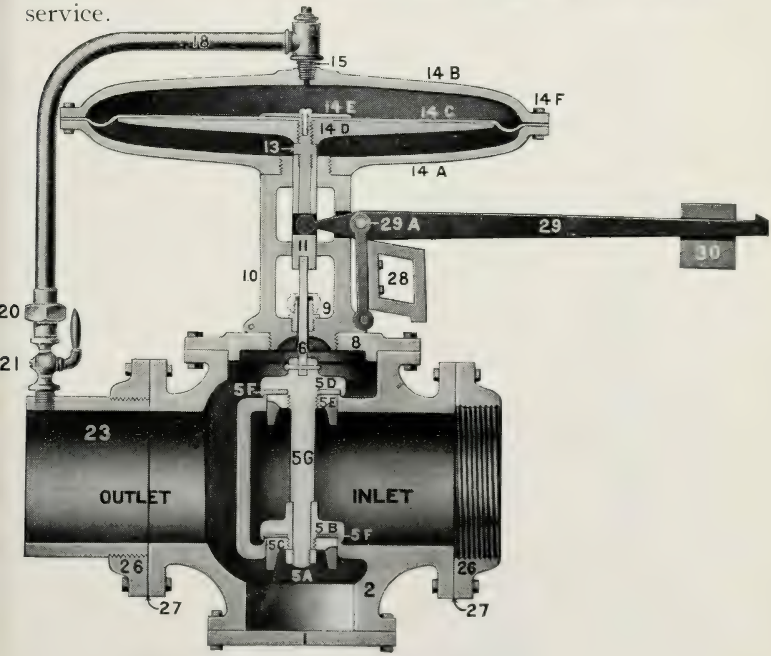


Fig. 158—LOW PRESSURE REGULATOR

Low Pressure Regulators—A low pressure regulator takes the gas from an intermediate pressure line and reduces it to a pressure low enough for home consumption, which is from four to six ounces.

A low pressure regulator is built with a large diaphragm and large valves and is very sensitive.

INDEX TO PARTS OF LOW PRESSURE REGULATOR SHOWN IN CUT

No. of Part	*Name of Part*
1	Bottom Plug or Cap
2	Main Valve Body
5	Valves and Connecting Stem Complete
5A	Bottom Valve Nut
5B	Bottom Valve
5C	Bottom Wing
5D	Top Valve
5E	Top Wing
5F	Top Valve Seats
5G	Connecting Stem
6	Lower Steel Stem
8	Top Cap
9	Stuffing Box
10	Upright
11	Upper Brass Stem
14A	Lower Diaphragm Cover
14B	Upper " "
14C	Rubber Diaphragm
14D	Lower Diaphragm Plate
14E	Upper " "
14F	Diaphragm Bolts
15	Close Nipple
18	Diaphragm Piping or Breathing Pipe
20	Brass Union
21	Special Diaphragm Cock
23	Main Line Nipple
26	Flanges Complete
27	Asbestos Gasket
28	Cut-off Link
29	Lever
30	Weight

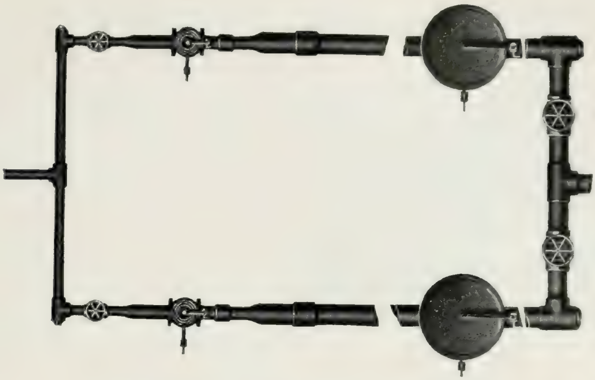


Fig. 159—LOW PRESSURE REGULATOR SETTING

Installing—Small size high and low pressure regulators set on the same line should be about six feet apart. With six-inch and larger size, set twenty feet or more apart, otherwise they are apt to work against one another. It is good policy to use a regulator of larger diameter than the diameter of the high pressure line. Proper gauges should be placed on the high, intermediate and low pressure side. If a by-pass is installed around a high pressure regulator, a gauge on the low or intermediate side should be placed in plain view from the by-pass gate.

It is a very good idea in low pressure systems to place a low pressure recording gauge on line, and preserve the charts for reference in case of dispute. Do not set regulators in a pit.

Regulator Diaphragms—Regulator diaphragms should be examined often, and if they show the slightest wear new diaphragms should be substituted for the old. The slightest pin hole in the diaphragm kills the effect of the regulator.

Regulator House—Fig. 160 shows regulator house built by the City of Medicine Hat, Alta. Ventilator is placed at either end of the roof. Panels in the wall are one brick thick. While this building is fire-proof, the cost is very reasonable.

Fig. 160—REGULATOR HOUSE

Regulators and Plain End Pipe—When a regulator is to be placed in a plain end pipe line, use two or three joints of screw pipe on the inlet and outlet of the regulator. Where the high pressure line enters the regulator station, the pipe should be well anchored.

Sheet Iron Heater for Gas Line—Figure 161 shows a sheet iron heater for use on a high pressure line entering a meter or regulator station. The large pipe projecting through the roof carries off the burnt gases and the small pipe runs into the pit to a point near the mixer of the burner in order to slowly supply fresh air. By this method the liability of the mixer receiving gusts of wind is eliminated and a constant fire is assured. A common log burner is used under the pipe.

Care of Regulators—Thaw a regulator with warm water. Do not use oil on a regulator piston rod in winter unless the excess of oil is wiped off, as cold weather chills the oil and causes the piston to stick.

If frost accumulates on the high pressure regulator, increase fire in the heater. If the regulator is frozen solid, care should be used in thawing it out even with warm water, as the regulator is apt to jump and throw high pressure gas into either intermediate or low pressure lines. In the above case it is better to close the gate back of the regulator first, and in event of the frozen regulator being the only feeding

point on a low pressure system, all consumers should be notified that gas will be turned on at a certain hour.

In case regulators are set where the distance between is so short that they jump, a short piece of pipe, the same size as that used between the two regulators, can be installed at right angles to old line and will act as a reservoir. This, of course, would be a blind end or short joint of pipe capped.

High and low pressure regulators should be visited daily and a record kept of all pressures unless recording gauges are used, in which case the charts can be preserved.

Fig. 161—SHEET IRON HEATER FOR GAS LINE

Heating—In cold weather, or where the reduction in pressure is greater than one hundred pounds, use a gas torch heater back of the small regulator installation. Place it far enough back so that in event of a gate flange gasket blowing out, the escaping gas cannot catch fire from the torch.

Regulator By-Pass—All high and low pressure regulators should be installed with a by-pass. This will enable one to properly clean, inspect, or repair them without interfering with the service ahead of the regulator.

Grinding Valves—When the seats or valves become nicked or worn and cause leakage they can be ground in by hand. Valves should be ground on their own seat, using emery flour and oil.

If a regulator fails to work and the diaphragm is found to be perfect, examine the valves and the pet cock on the breathing pipe running from the top of the diaphragm head to the low pressure side of the regulator. Dirt will cause the valves to stick and the pet cock to become choked

Fig. 162—LOW PRESSURE REGULATOR INSTALLATION
Note Single and Double Diaphragm Regulators

PART ELEVEN

Distribution of Gas

LOW PRESSURE SYSTEM — MAPPING — REGULATOR STATION — OIL SAFETY TANKS — SAFETY VALVES — GAUGES — LEAKS — SERVICES — PURIFIERS — RULES AND REGULATIONS FOR HOUSE PIPING.

Description of Low Pressure System—A low pressure system consists of a series or network of gas lines in which the gas is carried at a pressure of a few ounces above atmosphere. This low pressure is maintained in order to lessen the possibility of danger in house piping and burning devices, and at the same time to give adequate service to all consumers regardless of their distance from the regulating station.

It is good policy to use a double system of low pressure mains in city streets where there is a pavement or the possibility of one being laid in the future. In this case the mains should, if possible be laid between the curb and the sidewalk, one main on each side of the street.

In estimating the possible number of consumers in a city, figure five people to the meter.

Whenever possible, lines should be laid in alleys with services running into the rear of the building. There is less liability of damage suits due to accidents than if the lines are laid in much-traveled streets.

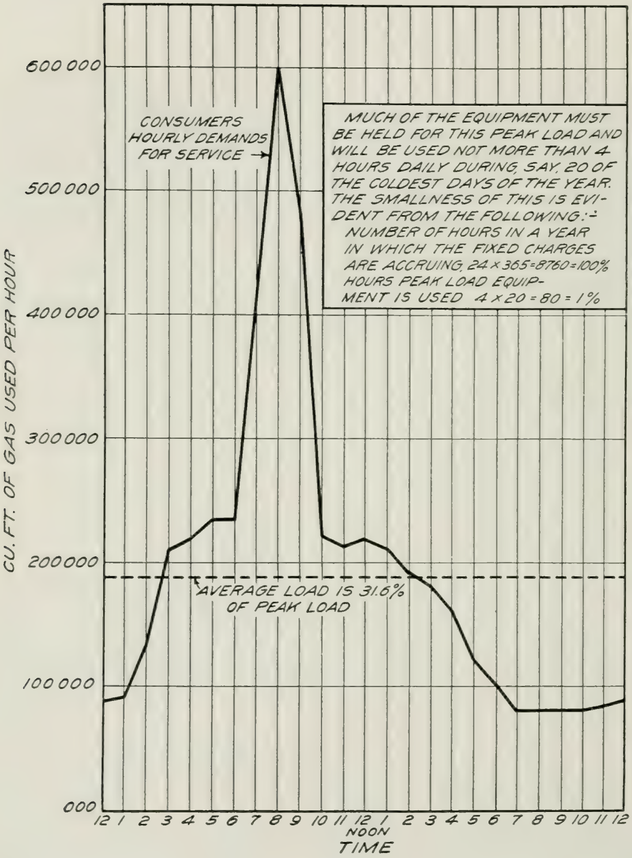


Fig. 163—CHART SHOWING DAILY PEAK LOAD OF LOW PRESSURE SYSTEM. (By S. S. Wyer in "Natural Gas Service.")

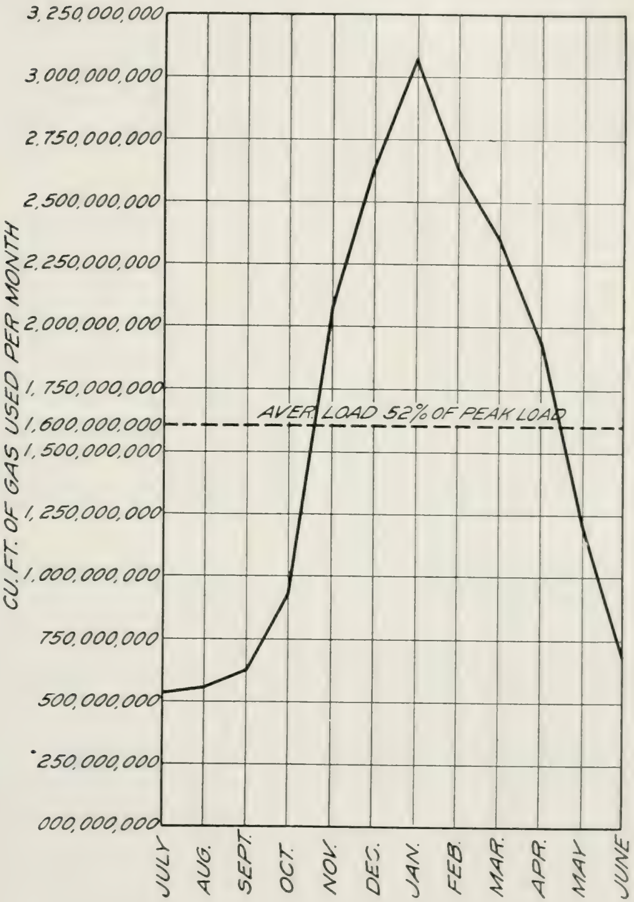


Fig. 164—AVERAGE MONTHLY PEAK LOAD (By S. S. Wyer)

Peak Load. Every natural gas company is confronted with the serious problem of peak load, and how to obtain an adequate return on the additional investment required. Abnormal peaks of very short duration are characteristic of all natural gas loads. This necessitates a large investment for equipment that is actually used only a very short period out of each year. Even though the peak load equipment is used for a few hours out of each year, the investment must be made to render the service.

Construction of Low Pressure System—Plain end pipe can be used to great advantage in a low pressure system. There should be no dead ends. In cities of 5000 or larger, use a belt line feeding system. This consists merely of feeding the gas from the high pressure line into a belt line at an intermediate pressure, which in turn is connected with different regulator stations where the gas is reduced to a low pressure of generally about four to six ounces. The pressure carried on the belt line should be between fifteen and twenty pounds.

Mapping—When a low pressure system is installed or any new additions made to an old system, it should be properly platted, showing all tees, plugs, expansion joints, bends and other fittings, as well as distances in feet, between streets and from curb to lines.

Size of Mains—Low pressure systems are too frequently installed with pipe of too small a diameter. The larger the main the better will be the service and the lower the pressure necessary to give it.

Table Showing the Approximate Discharge, in Cubic Feet per Hour, of Gas of 0.6 Specific Gravity in Different Lengths and Diameters of Pipe

Intake Pressure............4.0 oz. or 6.9 in. water
Discharge Pressure.........3.7 oz. or 6.4 in. water

(*By F. H. Oliphant*)

L'gh in Feet	Diameter of Pipe								
	1 Inch	2 Inch	3 Inch	4 Inch	5 Inch	6 Inch	8 Inch	10 Inch	12 Inch
50	350	2,072	5,775	11,935	21,000	33,250	69,300	122.500	194,600
100	247	1,462	4,075	8,422	14,820	23,465	48,906	86,450	137,332
150	203	1,201	3,349	6,922	12,180	19,285	40,194	71,050	112,868
200	175	1,036	2,887	5,967	10,500	16,625	34,650	61,250	97,300
250	152	899	2,508	5,183	9,120	14,440	30,096	53,200	84,512
300	143	846	2,359	4,876	8,580	13,585	28,311	50,050	79,508
350	136	805	2,244	4,637	8,160	12,920	26,928	47,600	75,616
400	124	734	2,046	4,228	7,440	11,780	24,552	43,400	68.944
450	115	680	1,897	3,921	6,900	10,925	22,770	40,250	63,940
500	110	652	1,815	3,751	6,610	10,450	21,780	38,500	61.160
600	102	603	1,683	3,478	6,120	9,690	20,196	35,700	56,712
700	95	562	1,567	3,239	5,700	9,025	18,810	33,250	52,820
800	88	520	1,452	3,000	5,280	8,360	17,424	30,800	48,928
900	83	491	1,369	2,830	4,980	7,885	16,434	29.050	46,148
1000	76	449	1,254	2,591	4,560	7,220	15,048	26.600	42.256
1100	73	432	1,204	2,489	4,380	6,935	14,454	25.550	40.588
1200	71	420	1,171	2,421	4,260	6,745	14,058	24,850	39.476
1300	68	402	1,122	2,318	4,080	6,460	13,464	23.800	37,808
1400	66	390	1,089	2,250	3,960	6,270	13,068	23.100	36,696
1500	64	378	1,056	2,182	3,840	6,080	12,672	22.400	35,584
1600	62	367	1,023	2,114	3,720	5,890	12,276	21,700	34,472
1800	58	343	957	1,977	3,480	5,510	11,484	20.300	32.248
2000	55	325	907	1,875	3,300	5,225	10.890	19.250	30.580
2500	50	296	825	1,705	3,000	4,750	9.900	17.500	27,800
3000	47	278	775	1,602	2,820	4,465	9.306	16.450	26.132
3500	42	248	693	1,432	2,520	3,990	8.316	14.700	23.352
4000	40	236	660	1,364	2,400	3,800	7,920	14,000	22,240
4500	37	219	610	1,261	2,220	3,515	7,326	12.950	20.572
5280	34	201	561	1,159	2,040	3,230	6,732	11.900	18,904

Welding Gas Mains—In welding gas mains, the pipe is strung along on top of the ground, outside of the trench. Two or more lengths of pipe are butted together and welded by an operator, assisted by two helpers, one at each end of the section. The helpers turn the section with chain tongs or other devices so that the operator is always welding on top of the pipe—a position in which the fastest work can be accomplished.

Fig. 165—WELDING LOW PRESSURE MAINS

Various engineers use different methods of handling the pipe for welding. While many follow the method described above for all sizes of pipe, some engineers weld the larger sizes, namely, 8, 10, 12 and 16 inches, supported on skids directly above the trench. In this way frequently two operators work on opposite sides of the pipe, which is turned, as the work progresses, by one or more helpers.

With the small oxy-acetylene flame, which has a temperature of approximately 6300 degrees, the metal on each side of the joint is heated to the fusion point, when pure Norway iron wire is fused into the molten metal, forming a true fusion weld. By this simple method the operator does the work, building up the weld to any desired thickness, making the joint as strong as desired.

Where the pipes are cut off straight, the two sections are butted up to within $\frac{1}{16}$ to $\frac{1}{4}$-inch of each other according to the size of the pipe, and the weld is made as described.

Fig. 166 — PORTABLE WELDING OUTFIT CONSISTING OF TWO STEEL CYLINDERS —ONE OF OXYGEN AND ONE OF ACETYLINE WITH REGULATORS, HOSE, ETC.

Figure 166 illustrates a welding unit most suitable for field use. The unit consists of two steel cylinders, one each of compressed acetylene and oxygen, welding blowpipe, necessary regulators, hose, etc. The entire outfit is mounted on a two-wheeled truck and is easily and quickly moved from place to place as required.

As fast as a section of welded pipe is finished it is capped at both ends and tested for leaks, under any desired pressure.

After the welded section has been tested and found satisfactory, it is rolled to the trench and lowered into place.

Although the pipe in the trench should be graded as carefully as is customary in ordinary practice, do care need be taken to have it lie absolutely straight. In fact the more snake-like the pipe lies in the trench, the better, as by this method contraction and expansion are taken care of. Common practice has demonstrated that because of the great strength and flexibility of the welded joint this is the only provision necessary to take care of expansion and contraction.

The section of pipe now in the trench is welded to the main already laid. For this, as for all welding in the trench, a bell hole is dug large enough to allow the operator to weld entirely around the joint. When welding the bottom of the pipe he is working overhead, a position in which good welding is readily accomplished after proper practice.

Where laterals are required, a hole of the proper size is cut in the main with the cutting blowpipe, and the lateral is welded into place at any angle desired.

One of the great advantages in this method of pipe line construction is the eliminating of joints, collars, sleeves, fittings, etc., thus greatly decreasing the leakage.

Low Pressure Main Marker—In laying a new low pressure system or renewing old mains, wherever the work is done at paved street intersections, it is good practice to place a "monument" directly over and connected by chain to the gas main cross or intersection. Top of "monument" should be level with the surface of the pavement and should be lettered to indicate it is the property of the gas company. It will always assist in locating the point of intersection of mains without running a survey or use of blue prints.

Regulating Station or Feeding Points—Regulating stations should be placed at advantageous points in the thickly settled sections of the city or town. The purpose of this is to maintain as nearly as possible, a uniform pressure through-

out the whole distribution system under conditions of "heavy pull," or large consumption of gas.

Low Pressure Regulator Station or Building—A well-built regulator house provided with a ventilator and neatly painted is a credit to any gas company.

Install a low pressure recording gauge, with either twenty-four hour or seven-day clock and chart on the low

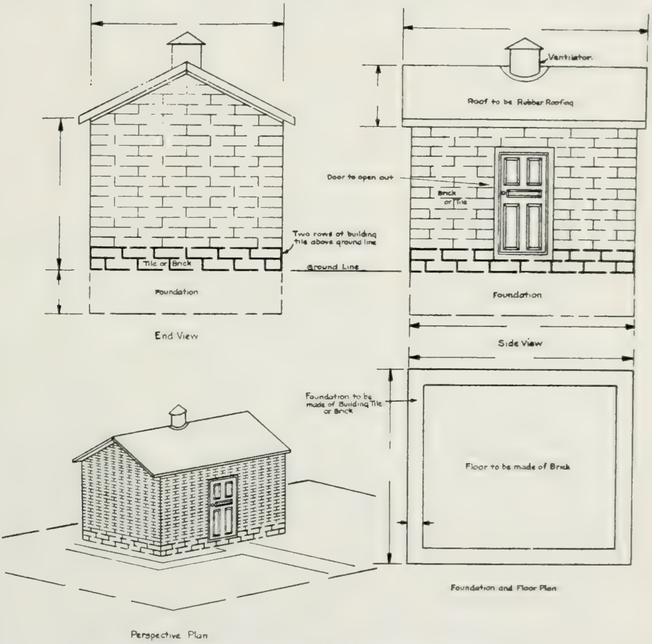


Fig. 167—PLAN OF REGULATOR BUILDING

side of the regulator, and require the charts to be turned into the main office as soon as taken from the gauge. This will not only show the continuous pressure on the mains but will also act as a check on the regulator inspectors or caretakers. In summer, when the consumption is low, the tendency of a caretaker is to neglect the inspection of regulators.

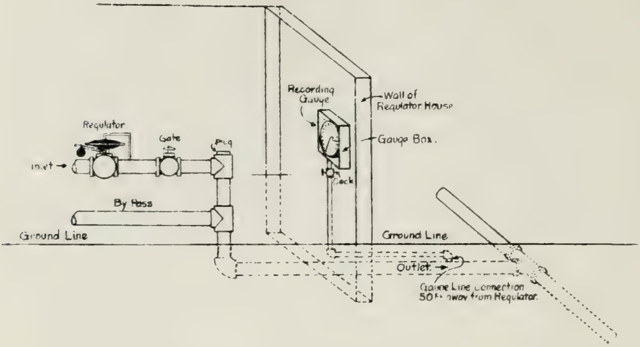


Fig. 168—SKETCH SHOWING INSTALLATION OF LOW PRESSURE RECORDING GAUGE AT REGULATOR STATION

Oil Safety Tank—An oil safety tank consists of a sheet-iron drum or cylinder of reasonable size with pipe flange connections on the top. The inlet to tank should be of the same size pipe as the low pressure main and should run down through the top of the tank to within six inches of the bottom. The outlet should consist of a short piece of pipe the same size as the inlet, to act as an escape for the gas, and where the tank is placed in the interior of a building the outlet should be continued to the outside. A sufficient quantity of oil is placed in the tank, to seal the end of the inlet pipe, the depth depending upon the pressure at which it is desired to have it blow. If the pressure exceeds this value it will overcome the head produced by the seal and the gas will escape through the tank and relieve the pressure on the main. As soon as the pressure drops back to its normal value the oil seal automatically closes the pipe again. A salt-water brine can be used instead of oil.

Fig. 169
LOW PRESSURE OIL SAFETY TANK

Turning Gas into New Low Pressure System—After turning gas into a new low pressure system and before opening any service cocks, the air should be let out slowly along various points of the line. After the gas has been first turned into the service, the air should be let out of the service through some stove or other opening by an inspector or competent employee of the gas company.

Fig. 170—TESTING A SECTION OF LOW PRESSURE SYSTEM WITH A SMALL AIR COMPRESSOR AND GAS ENGINE FOR POWER INSTALLED ON A WAGON

Testing Low Pressure Systems—In constructing a low pressure system it should be tested after each day's work with at least thirty pounds pressure of air or gas but not with a combination of the two. When using air pressure an air pump (steam driven) can be used, and where the system is large the air can be pumped in over night and the inspection made in the morning.

It is good policy to make a few service taps under pressure while testing. This will assist in cleaning the line as well as closing small leaks.

Leaks—While leaks can be closed around collars by caulking, it is better to use collar leak clamps. Collar leak clamps take better hold and need less tightening after put in use if the end of the collar has a flat face or surface.

Electrolysis—Electrolysis in a low pressure gas system is the destruction of pipe caused by stray electric currents from electric car lines. The damage is done to the gas main by the stray current jumping from the street car rail or ground onto the pipe and off again. It is an established fact that an alternating current does not cause electrolysis to nearly as great an extent as does direct current. The corrosion always takes place where the current leaves the pipe and enters the ground, whereas no harm is done at the point where the current enters the pipe.

Heretofore various remedies have been suggested in the nature of bonding. One of these methods was to connect each joint of pipe with the other by a copper wire properly attached to each joint to make a good electrical connection. The main was wired at the point nearest the dynamo station and the wiring connected with the negative bar of the dynamo. With this method the gas company's low pressure system became the return feeder for the electric car line company and practically a part of its electric system. In the event of a gas company repairing its main and temporarily breaking the gas line, there is great liability of an explosion of the gas leakage in the ditch ignited by a spark caused by the stray current at the moment of removing or replacing any joint of pipe in the main.

Electrolytic Mitigating System (Albert F. Ganz, Electrical Engineer)—"The insulated radial track return feeder system aims to relieve the tracks of current by insulated conductors and thus aims to prevent currents from escaping into the ground. With a properly laid out track return feeder system, together with properly bonded tracks, it is

possible and practicable to minimize stray currents through the ground and therefore stray currents on underground piping to any desired minimum value, and such currents may be made so small as to be negligible. This system, removes the cause of the trouble, in that it relieves underground piping systems of dangerous stray currents. It removes danger from sparking as well as dangers from electrolysis, and does not require changes to be made in the railway system when changes in the underground piping system are made. In fact it leaves underground piping systems separate and independent of railway systems, which is certainly a safer and more preferable condition than to deliberately make such piping systems a part of the railway return circuit and a carrier of return railway current.

With the tracks of two systems connected together, not only at cross overs, but also where necessary by cross bonding cables, these tracks become available for the joint use of the return currents from both systems with the result of greatly reducing the potential gradient in these tracks with corresponding reduction in stray currents through ground.

It is the unquestionable duty of those who distribute electric currents to so control them as to prevent such currents from damaging others. Good engineering practice of to-day makes it possible and practicable for single trolley electric railways to provide a return circuit which will prevent escape of large and serious stray electric currents into the ground. Where such large and serious stray electric currents are allowed to escape they become a source of danger to the lives and property of the public and to the property of other utilities and of the municipality. The escape of such currents should, in my opinion, be controlled through the enactment and enforcement of a suitable ordinance based on the police powers of the municipality, exactly as other nuisances which endanger the public are now controlled."

In connection with Mr. Ganz's article, the writer herewith cites an incident that happened in the city of Buffalo which fully bears out the statement that stray electric currents on gas and water mains are not only destructive to the main but often cause explosions at distant points from the main. In one of the fire engine buildings situated in the center of the city a tin gas meter was hung from the wall near the ceiling, in close proximity to a water pipe connected with the city water service. At the time of the accident several firemen then on duty were seated within plain view of the meter. Apparently, without any known cause, a flash occurred about the meter, melting same and instantly starting a fire, which of course on account of its quick discovery was easily distinguished without any great damage. If this had happened under most any other circumstances it very likely would have caused a disastrous fire.

While this case created considerable wonderment it was soon solved and the cause attributed to stray currents jumping from either the water pipe to the meter or vice versa and melting the solder on the meter.

With reference to the foregoing, it will be noted that on page 452 under "Installing Domestic Meters" the author states: "In cities having street car service do not set the meter near any water or artificial gas pipes."

ELECTROLYSIS REMEDIAL MEASURES.

"The following form of ordinance has been prepared for the purpose of providing regulations which will relieve dangerous conditions due to currents escaping from electrical distribution systems, which currents are a constant source of damage and create a serious hazard to the public and to the property of public utilities. The provisions of the ordinance are based upon the present state of the art as determined by extended studies and practical experience in this country and abroad. Considering the dangers to be guarded against and the magnitude of property interests to be protected, the provisions of this ordinance are, in our opinion, necessary and reasonable, and its enforcement will not impose an undue burden upon those affected by its terms.

ALBERT F. GANZ, Consulting Electrical Engineer, Professor of Electrical Engineering, Stevens Institute of Technology, Hoboken, N. J. HOWARD S. WARREN, Engineer, American Telephone and Telegraph Company, New York, N. Y. SAMUEL S. WYER, Consulting Engineer, Columbus, Ohio.

New York, N. Y., April 11, 1913.

ORDINANCE No......

To Protect the Lives and Property of Persons From Danger Due to Stray Electric Currents Through Ground.

WHEREAS, electric currents escaping into the ground from electrical distribution systems are a constant source of danger to the lives and property of the public and a constant source of injury to underground water-pipes, gas-pipes, cable-sheaths, and other underground metallic structures; and,

WHEREAS, it is deemed necessary for the general safety of the public and the necessary conduct of the public service to restrict and limit the escape of electric currents from electrical distribution systems:

BE IT ORDAINED by the Council of the........... of....................................., State of Ohio:

SECTION ONE. It shall be unlawful for any person, firm or corporation to construct, operate or maintain within the limits of the municipality of........................ any system of circuits used by such person, firm or corporation, for carrying electric currents, which system at any one time conveys from any one point to any other point more than one (1) kilowatt of electric power, unless such current-carrying electric circuits are so constructed, operated and maintained as to fulfill the requirements hereinafter set forth.

SECTION TWO. All metallic conductors forming parts of such current-carrying electric circuits shall be insulated from the ground wherever it is practicable so to insulate them; or if in the case of any particular metallic conductor such insulation shall be impracticable, then and in such case the said particular metallic conductor which can not be insulated shall be so constructed and maintained as to afford as high a resistance to ground as practicable.

SECTION THREE. Whenever any such metallic conductors forming parts of such current-carrying electric circuits are not insulated from the ground, such circuits shall be designed, installed, operated and maintained, so that the average potential difference during any ten (10)

consecutive minutes between any two (2) points one thousand (1,000) feet apart on said metallic conductors will not exceed one (1) volt, and further, so that the average potential difference during any ten (10) consecutive minutes, between any two (2) points more than one thousand (1,000) feet apart within the limits of........................ on such metallic conductors, will not exceed seven (7) volts.

SECTION FOUR. To aid in determining whether or not the requirements of this ordinance are being complied with, every person, firm or corporation referred to in Section One hereof, constructing, operating or maintaining metallic conductors not insulated from the ground, forming parts of such current-carrying electric circuits, shall provide and maintain insulated potential wires extending from some common point located within the limits of .... to an adequate number of points on said metallic conductors, such points to be designated from time to time by the authorized representative of the municipality, and such person, firm or corporation shall also provide an adequate number of voltmeters so arranged with reference to the said insulated potential wires that the potential differences between the said points on said metallic conductors may be readily and accurately measured; and the potential differences between some one of said points and each other of the said points, as determined by readings of said voltmeters taken at least once every thirty (30) seconds during ten (10) consecutive minutes, shall be measured and recorded, said readings to be taken at least once every week, on a business day, during the one (1) hour of maximum difference of potential. In lieu of such readings there may be substituted the continuous records from an adequate number of recording voltmeters installed as aforesaid. The authorized representative of the municipality and any other interested person shall have access to such potential wires, voltmeters and records, and shall have the right to be present and witness such measurements, and shall further have the right to make such additional measurements as he may consider necessary or desirable.

SECTION FIVE. Any person, firm or corporation violating any of the provisions of this ordinance shall, upon conviction, be fined not more than Three Hundred Dollars ($300.00) for each offense, and each day's operation of such

system of current-carrying electric circuits contrary to this ordinance shall constitute a separate and distinct offense.

SECTION SIX. This ordinance shall take effect and be in force from and after four (4) months from its passage and legal publication."

The foregoing ordinance has been adopted by several cities in Ohio, and in one instance validated in court.

Fire Alarm in Gas Office—Some gas companies, especially in the South where wood construction predominates and cellars are lacking, have installed a fire alarm (same as at a fire engine house) in the superintendent's or other office of the company and have a man on duty both day and night with motor cycle and tools, to answer all alarms. In case of an explosion it permits the gas company to obtain first hand information.

Gauge Alarm—When it is desired to make a gauge alarm to be used either on a high pressure line entering a low pressure feeding station or on an intermediate or belt line pressure, the following method can be employed: use an ordinary spring gauge and drill a $\frac{1}{8}$-inch hole about 1 inch from the outer circumference of the glass dial. Remove the insulation from the end of a wire and insert same into the hole in the glass dial to within $\frac{1}{16}$-inch of the graduated gauge dial, taking care, however, that it does not touch the latter. Attach another wire to the pipe leading to the gauge. The two wires can be strung any distance to a common electric bell and dry batteries. The wire in the glass dial of the gauge should be turned to a position opposite the pressure on the dial at which it is desired that the bell should ring. When the pressure drops to this point, the gauge hand will make a contact with the wire, thereby causing the bell to ring.

Stealing Gas—The consumer who tampers with a gas meter, or uses a by-pass to obtain gas without registration,

commits a crime the same as though he walked into the gas office and stole money from the cash drawer.

Many companies, especially those employing the continuous meter reading system, offer a regular scale of rewards to their meter readers and employees for detecting by-passes, tampered meters (diaphragm punctured, or otherwise injured to cause meter to run slow) tipping meters, leaks at meters, leaks in street, etc.

Some companies are paying the following rewards:

By-pass (whole house)	$2.00
Straight connection	1.00
Line off service	.75
Leak in meter case	.10
" at dial	.05
Meter binding	.10
Not registering on low fire	.15
Not registering	.50
Leak in service curb box	.10
Leak in main line	.25
Using auto. tires over 3500 miles	1.00

Some meter readers reading meters continually use the extra three or four days a month not employed in reading, to scout about their route and find gas steals or leaks. When this method is employed the salary paid is usually under the customary salary paid for reading meters only. The rewards bring the amount of money earned to above the regular salary.

Employees soon become exceptionally keen in detecting the odor of escaping gas or in finding gas steals.

A similar method is employed with bookkeepers in detecting gas steals. The bookkeeper keeps continual watch on the amount of each month's gas bill. If he finds it particularly small he reports it and if it proves to be a case of gas stealing he is rewarded accordingly.

Suggestions to Gas Companies and Employees—Never forget the danger and results of a gas explosion. One careless act may cost the company a $10,000 law suit. Polite-

ness and courtesy in dealing with consumers will overcome the natural suspicion the public holds toward the gas company. Practically all suspicion of gas company's methods starts with the employees or representatives.

Remember in talking to a consumer that you—at one time—knew as little about natural gas as the consumer you are talking to.

A good complaint man is the most valuable of employees of a gas company.

Never leave a large leak unrepaired or unguarded.

Do not depend upon sense of smell, hearing, rain, or flies to determine if your low pressure mains are gas tight. None of the foregoing will tell you accurately or conclusively. Except to ditch down to the main—the bar test is the only accurate method of determining leaks in gas mains.

It is good practice, in cities, to take samples of gas from sewer manholes and have the gas analyzed. The results will show the percentage of natural gas to air or sewer gas. Gas will travel through an entire sewer system. If any natural gas is shown in the analysis, find the manhole showing the greatest percentage of natural gas, then look for leaky mains in that vicinity. In one city the writer found a gas engine working with gas sucked from a sewer. In this instance the leak which had been caused by electrolysis, was located one block away from the engine. After the leak had been repaired the gas engine was compelled to receive its gas through a gas meter.

Wireless Pipe Locator—This instrument consists of a special form of vibrator and an induction coil with six batteries, together with detector coil and receiver for tracing the circuit. The advantage of this outfit is that it enables the operator to locate lost gas services, mains or water pipes under the ground between two points.

In operating the locator it is necessary to attach one wire to the main in the street or curb box and the other wire

to the gas service in the building or on the main at the other known point. After attaching the wires at these two points the operator can trace the pipe intervening between the two points by holding the receiver to the ear and following the noise or tone.

In noisy streets or where the line lays deep it is necessary to use from ten to twelve dry cells.

It will not locate stub lines, but only a pipe line between two points where wires can be properly attached.

Where gas lines in a house are connected with a hot water heater, disconnect the gas meter and make connection on the inlet connection of the service line. Otherwise part of the current is liable to follow the water lines, making it hard to detect the tone.

Fig. 171—PULMOTOR BEING USED TO RESTORE LIFE TO A PERSON OVERCOME BY GAS

Purifiers for Natural Gas for Domestic Service—Where natural gas contains a high percentage of sulphur gas, the excess can be removed by using a small tank holding about a bushel of shavings and oxide of iron and provided with a cover flange that will permit the removal and changing of the shavings and oxide of iron at least once a year. It is practically the same process in a small way as is practiced in the producer gas plants.

This tank should be installed on the inlet side of the domestic meter. As there are only a few instances in the country where this purifying of natural gas is necessary, the gas companies are obliged to have their own tanks specially built.

The tank might be described as being about the size of a dish pan with a cover, the inlet and the outlet on the opposite sides. The outlet and inlet connections are generally for 1-inch or 1¼-inch pipe.

Safety or Pop Valves—Where metal safety valves are smaller in diameter than the size of the main, they will not take care of a sudden rise of pressure in a low pressure main. In order to be effective the safety valve should be of the same diameter as the gas main.

Oil tanks can be used only on low pressure system. For high or intermediate pressure, use a specially made safety valve. This style of valve is generally used on intermediate or belt line pressure.

Low Pressure Gauges—The mercury gauge which is most commonly used on low pressure systems consists of a cast-iron body, and a glass tube for the mercury column, with a scale (in pounds) back of the glass tube. Each space is divided into sixteen parts or ounces, each large division representing one pound. This gauge is not read in tenths of one inch but in ounces and pounds, and is made in 3, 5, 7, 10, 15, 20, and 25 lb. sizes.

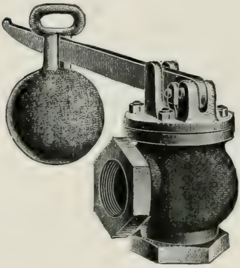


Fig. 172—SAFETY VALVE

Siphon or "U" Gauges—These are the most convenient low pressure gauges in use, being portable and simply screwed to the piping wherever it is desired to take the pressure.

They consist of a U-shaped tube made of one piece of glass tubing bent to shape in sizes from 4-inch to 10-inch; and, in larger sizes, of two straight glass tubes connected at the bottom by a brass bend. Between the two sides or legs of this tube is set a scale graduated in inches and tenths, or pounds and ounces, as desired. A bent brass tube, or goose-neck, is connected to the "U" tube at the top and runs down the side to the gas connection. A filling screw is provided for the water or mercury and a vent where the goose-neck is connected to the "U" tube to relieve the gas pressure on the inlet side after shutting off the gas at the pipe.

When used the gauge is filled with water or mercury to the center of the scale, which is zero. The gauge is connected to the gas supply and the pressure turned on. The liquid will fall below zero on the inlet side of the "U" tube and rise on the opposite side the same distance. The distance between the two levels of the liquid as shown by the scale will give the amount of pressure in inches and tenths or in pounds and ounces, according to the graduation.

While the gauge is in use the downward motion of the liquid in one column, due to the pressure of the gas, should equal the rise of liquid in the opposite column. In case the water, after being set at zero, should not drop on the pressure side as much as it rises on the other side, it is an indication that the glass tubes are not of equal diameter, and both columns must be read, their sum being the true pressure.

Water is generally used in siphon gauges in testing domestic meters and measuring small gas wells. It is also used in testing large capacity meters in the field.

The glasses in the sizes from 4-inch to 12-inch are set in with special cement. The other sizes have the joints set with rubber gaskets tightly screwed up, which permit of broken glasses being readily removed and replaced.

The scales are of boxwood and the graduations and figures are clearly marked.

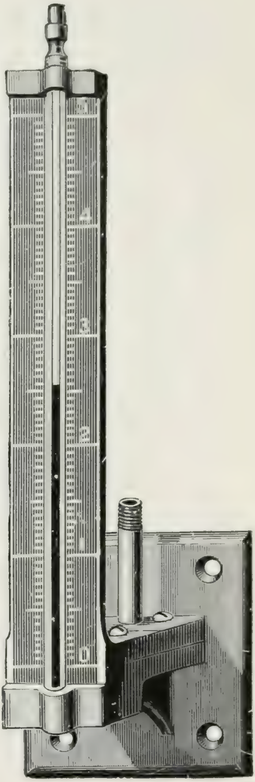


Fig. 173—MERCURY PRESSURE GAUGE

The 4-inch gauge is fitted with a ground joint for convenience in making connections when carried about the district. The bottom section of the ground joint has an inside thread, $\frac{1}{8}$-inch iron pipe size. From the 6-inch size up, the gauges have screw connections for suitable iron pipe sizes.

The sizes usually manufactured run from 4-inch to 24-inch (by 2-inch steps). Larger sizes than 24-inch can be made specially to order.

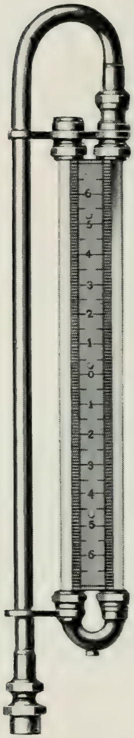


Fig. 174—SIPHON OR "U" GAUGE FOR LOW PRESSURE

These gauges are also made with square ends and fitted with gaskets so that if the glass should be broken it can be easily replaced and with lower bracket of iron in case they are desired to be used with mercury. They can also be fitted with a metal scale if so required.

Differential Gauges—These are of the siphon or "U" gauge form mounted on an oak board. The "U" tube has a cock at the top on each side and is connected at one side to one line of gas and at the other side to another line.

The pressure in either line can be indicated or the difference in pressure between the two lines. When both top cocks are closed and both lines of gas are on the gauge, the difference in pressure can be read on the scale. When either line of gas is shut off and the top cock on that side is opened to the air, the pressure in the other line is indicated, as with an ordinary siphon gauge. They are made in sizes from 6-inch to 30-inch by 2-inch steps.

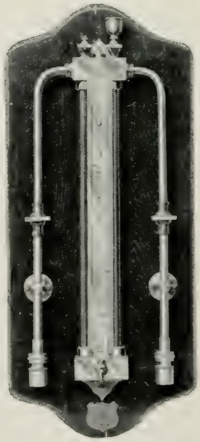


Fig. 175—DIFFERENTIAL GAUGE

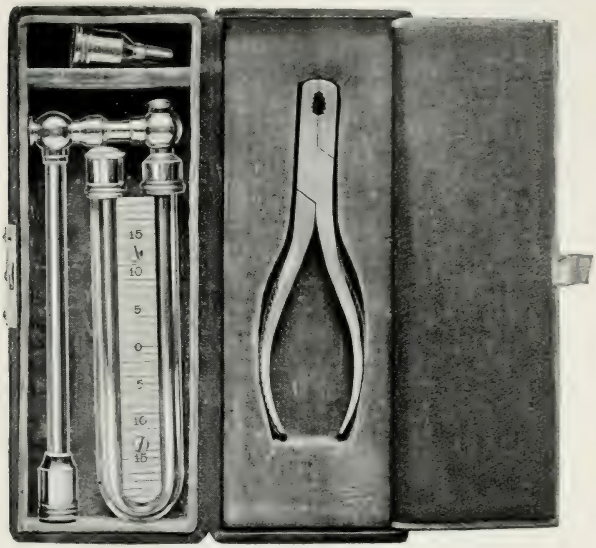


Fig. 176—POCKET GAUGE

The Equivalents of Ounces, per Square Inch, in Inches of Height of Columns of Water and Mercury.

Ounces	Inches of Water	Inches of Mercury	Ounces	Inches of Water	Inches of Mercury
.146	0.25	.018	7	12.11	.892
.292	0.51	.037	8	13.85	1.019
.438	0.76	.055	9	15.58	1.146
.584	1.01	.074	10	17.31	1.277
1	1.73	.127	11	19.05	1.401
2	3.46	.255	12	20.78	1.528
3	5.19	.382	13	22.51	1.655
4	6.92	.510	14	24.24	1.783
5	8.65	.637	15	25.97	1.910
6	10.38	.765	16	27.71	2.037

27.71 inches of water and 2.0374 inches of mercury equal one pound per square inch at atmospheric pressure and 62 deg. fahr. temperature. Mercury is 13.59 times as heavy as water.

SERVICES AND HOUSE PIPING—(Section)

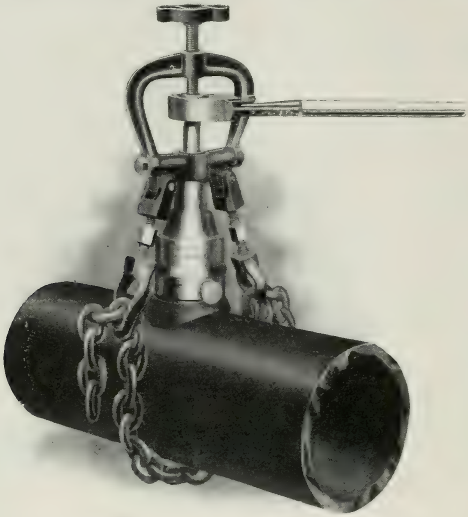


Fig. 177—TAPPING MACHINE

Tapping for Services—Tapping machines for making taps for services in low pressure mains are found very practical. By using the cup in making the tap, considerable gas can be saved that otherwise would be lost.

Care should be used to note that the machine is absolutely tight on the main before starting to drill.

PROPER SIZE TAP DRILLS TO BE USED FOR THE DIFFERENT SIZED PIPES.

Nominal Size Inch	Tap Drill Inch	Nominal Size Inch	Tap Drill Inch
1/8	11/32	1 1/2	1 3/4
1/4	7/16	2	2 1/4
3/8	9/16	2 1/2	2 11/16
1/2	11/16	3	3 5/16
3/4	15/16	3 1/2	3 13/16
1	1 3/16	4	4 5/16
1 1/4	1 1/2		

Fig. 178—COMMON CURB BOX

Services—In tapping a low pressure gas main for domestic use, connections should be made with two street ells. Do not use smaller than 1¼-inch ell or service. The larger the pipe the better the service. Stop cocks should be placed on the service near the curb on the walk side and a curb box placed over same. Prior to placing the stop cock in the line, the core of same should be oiled to enable it to be easily turned by a long wrench, purposely made for use in curb boxes.

Expansion sleeves can be used to good advantage. If the street service and curb box are installed first and the service line laid by a plumber or gas fitter later, should be slightly out of line, the sleeve will take care of the discrepancy and make a tight joint. Leave a 10- or 12-inch nipple on outlet of curb cock to be used for sleeve connection. Nipple should be capped or plugged on outlet side till sleeve and service are laid.

Steel Pipe—Do not use small-sized steel pipe in house piping where it is desired to make any bends in the pipe.

Testing House Piping—After piping a residence for natural gas and before turning the gas into the piping, an air test should be made with fifteen pounds pressure on the house piping prior to connecting house piping to meter.

This test should be made in the presence of a representative of the gas company before a permit is issued to the consumer to use gas. The method of detecting leaks under air pressure is either by using soap suds applied to the joints or using ether in the air that is pumped into the line.

In making this test, the test gauge should be placed in a vertical position.

Fig. 179—GAS PROVING PUMP AND GAUGE

Gas Proving Pump and Gauge—Fig. 179 shows a gas proving pump and gauge used for making air tests in house piping. A common spring gauge can be used instead of mercury column. The pump is equipped with cup for admitting ether into piping, in which case leaks can be detected from the smell of leaking air and ether.

Rules and Regulations for Gas Fitting—For a complete set of rules and regulations for house piping, setting up domestic meters, etc., the following suggestions are submitted. While various companies publish different rules, an effort has been made to select such rules and regulations as are most generally used.

Rule 1—In piping new houses the gas company will decide where gas meter shall be located and the fitter shall extend the riser to terminate within 18 inches of the proposed location of the meter and to the right of same.

Rule 2—Provision must be made to place the meter on a solid support where it can be conveniently read and protected from the weather. Meters shall not be located under side-walks, or show-windows, near furnaces or ovens; locked in compartments, or placed in other positions where they will be inaccessible to adjust. Under no conditions shall plumbers, fitters or other parties disconnect any meter, connect to, or disturb piping on inlet side of meter after once set.

Rule 3—To accommodate different tenants the company will set as many meters as there are separate consumers

in a given building, connecting the meters to one service pipe, providing the service is large enough to provide an ample supply, and that the risers or pipes leading to the different tenants are extended to within 18 inches of the proposed locations of the meters.

Rule 4—Risers must not be scattered but must be dropped together in alignment to the room where meters are set. They must be kept at least three inches apart and extended not less than twenty inches from the floor.

Rule 5—Elbows and not tees shall be used on all meter inlet connections. All connections or disconnections of meter for any purpose will be made by employees of company only.

Rule 6—All gas pipes must be graded from meter to risers, free from traps or sags and properly supported with screws and gas pipe hooks or hangers. When it is impossible to prevent a trapped gas pipe, a suitable drip shall be provided, consisting of a nipple and cap located in an accessible place.

Rule 7—Rubber hose connections or fittings arranged for rubber hose connections for gas heaters or similar appliance will not be allowed.

Rule 8—Cement shall not be used or caulking done to repair faulty fitting work, and all imperfect fittings must be replaced.

Rule 9—In no case shall valves or unions be placed between ceiling and floor or in an inaccessible place so that the stuffing box of the valves cannot be repacked or union gasket replaced.

Rule 10—Where globe valves are used on fire connections, the stems must be packed with asbestos packing. "Soft seat" valves must not be used.

Rule 11—In running a line through a flue great care must be taken to see that pipe and fittings are free from defect.

Rule 12—Lead pipes must not be used under any circumstances.

Rule 13—Use as few elbows as possible. Elbows not absolutely necessary will be condemned. When impossible to get through an obstruction such as a beam, off-set the pipe rather than use elbows.

Rule 14—Cast iron fittings will not be permitted.

Rule 15—Air mixers must not be placed in air-tight ash boxes, but where a free flow of air can reach them at all times. Use adjustable mixers.

Rule 16—The burr left on inside of gas pipes must in every case be reamed out.

Rule 17—All outlets or risers where fixtures are not placed must be left securely capped.

Rule 18—All drops and openings for lights must project at least 1 inch beyond plaster of wall or ceiling, and must be securely fastened to joists or studding or to notched or cross pieces fastened to joists, or upright studding.

Rule 19—Unions or bushings shall not be used excepting to connect stoves or fires.

Rule 20—No more than one elbow will be allowed between burner and mixer.

Rule 21—Burners must have threaded connections. "Slip joints" will not be allowed.

Rule 22—In re-modeling or extending old gas piping, connections must be made where sizes can be maintained. If this cannot be done, a new line must be run to meter.

Rule 23—All gas piping must be tested with air pressure on a mercury or spring gauge showing ten pounds, which shall be maintained for fifteen minutes without falling. Gas will be turned on by an authorized agent of the company only, after such test has been properly made and report of same filed with the gas company. If meter stop is closed,

do not open under any circumstances. Application must be made to the company for gas to be turned on. Fire tests will not be allowed under any circumstances on inside work.

Rule 24—Where pipe runs through a stone or brick wall opening around the pipe must be cemented.

Rule 25—Place a damper in all stove-pipe and chimney throats.

The tables following shall govern the greatest length of pipe of the various sizes specified to be used for fuel and illuminating purposes:

For 1 Stove, 1-inch Pipe.
For 2 Stoves, 1-inch Pipe to first, ¾-inch to second.
For 3 Stoves, 1-inch Pipe to first and second, ¾-inch to third.
For 4 Stoves, 1¼-inch Pipe to first and second, 1-inch to third ¾-inch to fourth.

Gas Lighting

Size of Pipe Inches	Greatest Length Allowed Inside Building Feet	Greatest Number of Burners
⅜	15	1
⅜	10	4
½	25	6
¾	40	15
1	70	35
1¼	100	60
1½	150	100
2	200	200

¼-inch pipe will in no case be allowed.

Gas Ranges

Size of Pipe Inches	Greatest Length Allowed Inside Building Feet
¾	40
1	70

Automatic Water Heaters

Heater No.	Size of Pipe Inches	Greatest Length Allowed Inside Building Feet
3	1	70
4	1¼	100
6	1½	100
8	2	125

Instantaneous Water Heaters

Size of Pipe Inches	Greatest Length Allowed Inside Building Feet
¾	40
1	70
1½	100

Fires

Size of Pipe Inches	Greatest Length Allowed Inside Building Feet	Number of Fires
½	10	1
¾	30	1
1	100	1
1¼	350	1
¾	20	2
1¼	60	2
1¼	160	2
1	40	3
1¼	120	3
1	20	4
1¼	90	4
1¼	70	5
1½	125	5
1¼	40	6
1½	90	6
1½	30	7
1½	75	7
1¼	15	8
1½	50	8
1½	40	9
1½	30	10

Hot Air Furnaces

For hot air furnaces, boilers, etc., using burners having two or three mixers, use 1¼-inch pipe.

Capacities of Orifices—The capacity per hour, in cubic feet, of thin orifices similar to openings in air and gas mixers is given in the following table; the plate one-eighth inch thick and the pressures as indicated.

Capacities of Thin Orifices in Cubic Feet per Hour.

Diameter of Orifice Inches	Pressure (Inches of Water)					
	1	1.7	3.4	5.2	6.9	8.6
	Capacity per Hour (in Cubic Feet)					
5/64	6.3	8.2	12.5	15.9	18.4	20.
3/32	10.3	13.6	19.4	23.9	27.3	30.7
7/64	13.3	18.4	26.5	32.1	37.4	41.1
1/8	20.4	26.5	37.1	45.9	53.2	57.8
5/32	25.4	34.7	49.8	61.6	72.	80.3
3/16	40.2	52.9	79.5	95.7	111.	124.
1/4	61.	82.5	119.	147.	168.	191.
3/8	131.	178.	253.	300.	352.	400.
7/16	173.	229.	333.	409.	467.	529.
1/2	222.	294.	418.	514.	600.	654.

Note—The above table was made from actual tests.
Specific Gravity of gas 0.64.
Atmospheric pressure 14.4 pounds.
Measurement basis 4 ounce.

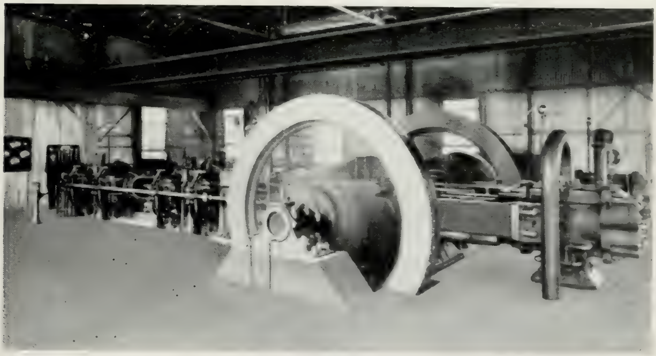


Fig. 180—INSTALLATION OF FAIRMONT GAS AND LIGHT CO., FAIRMONT, W. VA. Showing two 300 H. P. Single Tandem Gas Compressors

PART TWELVE

Income and Office Suggestions

INCOME—PER CAPITA INCOME TABLES—SERVICE APPLICATION—DOMESTIC METER INSTALLATION FORM—METER DEPOSIT CARD—OFFICE GAS BILL CARD—METER READER'S RECORD SHEET AND VARIOUS REQUEST, REMITTANCE AND RECEIPT FORMS.

Income—The average annual income of a domestic meter in small cities where natural gas sells for 25 cents per thousand cubic feet is approximately $30. In large cities the average will be slightly higher. The foregoing is true in the southern as well as in the northern states.

Percentage of Natural Gas Sold for Domestic Purposes Each Month in the Year 1908 in the Following Cities in the State of Kansas:

	Topeka	Lawrence	Kansas City
January	13.88	16.23	15.83
February	15.18	16.60	17.15
March	13.43	11.50	11.22
April	8.83	7.14	7.39
May	6.61	5.39	5.67
June	3.81	2.66	2.77
July	3.13	2.04	2.42
August	2.74	2.07	2.43
September	3.20	2.44	2.98
October	4.73	7.26	6.20
November	10.13	10.62	10.64
December	14.33	16.05	15.30
	100.00%	100.00%	100.00%

Table Showing Number of Domestic Meters Required for Towns and Cities of Different Population, Approximate Amount of Gas Required to Supply Same on the Coldest Day and the Approximate Income with Gas at 25, 30 and 35 Cents per Thousand Cubic Feet.

*Population	Number of Meters	Approximate Amount of Gas Required for Coldest Day Cu. Ft.	Approximate Annual Income		
			At 25c per 1000 Cu. Ft.	At 30c per 1000 Cu. Ft.	At 35c per 1000 Cu. Ft.
1,000	200	200,000	$ 6,000	$ 6,800	$ 7,400
2,000	400	400,000	12,000	13,600	14,800
3,000	600	600,000	18,000	20,400	22,800
4,000	800	800,000	24,000	27,200	29,600
5,000	1,000	1,000,000	30,000	34,000	37,000
7,000	1,400	1,400,000	42,000	47,600	51,800
10,000	2,000	2,000,000	60,000	68,000	74,000
15,000	3,000	3,000,000	90,000	102,000	111,000
20,000	4,000	4,000,000	120,000	136,000	148,000
25,000	5,000	5,000,000	150,000	170,000	185,000
30,000	6,000	6,000,000	180,000	204,000	222,000
40,000	8,000	8,000,000	240,000	272,000	296,000
50,000	10,000	10,000,000	300,000	340,000	370,000
60,000	12,000	12,000,000	360,000	408,000	444,000
70,000	14,000	14,000,000	420,000	476,000	518,000
80,000	16,000	16,000,000	480,000	504,000	592,000
90,000	18,000	18,000,000	540,000	612,000	666,000
100,000	20,000	20,000,000	600,000	680,000	740,000

*No allowance made for colored population.

Fig. 181.

2-8-12

APPLICATION FOR GAS SERVICE TO BE LAID

SERVICE APPLICATION

FORT WORTH........................19... SERVICE ORDER NO..................

JOHN DOE GAS COMPANY

IS HEREBY REQUESTED *by the applicant, representing............self, the owner/tenant of the.........*

property herein described. Lot............., Block.................Addition, to introduce....
its Service Pipe into the premises known as

No...Street/Avenue

as soon as practicable from its main gas pipe in such street in front or side of said premises, or alley in rear. This application is made with the understanding that service from main to curb line and curb box and stop will be put in free, and the undersigned agrees when service has been introduced to pay therefor from curb line to meter according to Rules and Regulations established by said Company, and in accordance with schedule of prices on back hereof.

Meters will not be set until service bill has been paid.

DO NOT SIGN UNTIL AFTER YOU HAVE READ.

....

To be signed by owner/tenant of property

Send Bill to...Street/Avenue

Fig. 182—SERVICE APPLICATION FORM

APPLICATION FOR GAS

No. . . . . *Fort Worth, Texas,* . . . . *191* . . . .

To JOHN DOE GAS COMPANY

Subject to the rules and regulations of your Company, as printed on opposite side of this card, I hereby make application for Natural Gas by Meter at . . . . *Street, Fort Worth, Texas, occupied as* . . . . *and in consideration of the delivery of Gas to me by* JOHN DOE GAS COMPANY, *I agree:*

To pay for Gas delivered to the premises above named at the published rates of the Company, on or before the 10th of the month following that in which gas was supplied, and to settle all bills thereafter at the office of the Company during its regular business hours, excepting that all bills shall become due and payable forthwith in cases of discontinuance of the use of Gas.

Name . . . . *Meter Dep. No.* . . . .

Business Address . . . . *Amount $* . . . .

Amt. Collected

Service Line Old New . . . . *on Service Line $* . . . .

(If New service collect to cover same)

House Piping Old New . . . . *Inspection* . . . .

Inspector's O. K. Received . . . . *A. M. P. M.* . . . .

No. of Set Order . . . . *Issued* . . . . *191* . . . .

Remarks . . . . *191* . . . .

Fig 183—GAS APPLICATION FORM

DOMESTIC METER INSTALLATION RECORD

Doesville Gas Company

App. No.

Fort Worth, Texas, ... 19...... No. 24933

Connect Meter	Disconnect Meter
For John Doe	For ....
815 Main Street	.... Street
Remarks	Remarks ....
Deposit #9006 $5.00	
Connected Meter No. 336420	Disconnected Meter No. ....
Kind Metric	Kind ....
State 365 400	State ....
Date 8-22-1912	Date ....
O.K. Thaman Fitter.	.... Fitter.
Entered Ledger, folio 235 line 21	Entered Ledger, folio .... line ....
Entered Meter Index, folio 58	Entered Meter Index, folio ....

Instructions—Fitter must use indelible pencil for filling in his portion of this blank. If the fitter makes a mistake in entering "State" he is not to erase the figures first written, but should run his pencil through same and then insert correct figures.

Fig. 184—DOMESTIC METER INSTALLATION RECORD FORM

(Reduced in Size Approximately One-Half)

METER DEPOSIT RECORD CARD

DEPOSIT NO. ....

NAME ....

	INTEREST PAID.	
....	To .... $	....
....	To .... $	....
....	To .... $	....
....	To .... $	....
....	To .... $	....
....	To .... $	....

Fig. 185—METER DEPOSIT RECORD CARD

STATE OF METER.

A No. ______

John Doe
1122 Peach St.

S 6 No. 35984 On 2-17-05 Off 11-4-14 2705.4
" G.E.A. " 4571 " 11-4-14 16.3 "
" " " "
" " " "

S.	201 16	L. No.		
1915	**1916**	**DATE**	**1917**	**1918**
		Jan.		
		Feb.		
		Mar.		
		Apr.		
		May		
		June		
		July		
		Aug.		
		Sept.		
		Oct.		
		Nov.		
		Dec.		

Fig. 186 METER READER'S RECORD SHEET
(To be used in loose leaf binder)

PLEASE BRING IN THIS CARD

POSTAL CARD GAS BILL

To the FORT WORTH GAS COMPANY, Dr.

1001 Throckmorton (Opp. City Hall)

OFFICE HOURS: 8.30 a. m. to 5 p. m. FORT WORTH, TEXAS Office Open on Last Day of Discount until 8 p. m.

Gas by Meter, 1912.

State Present Month..............000

State Last Month................000

Cubic Feet Consumed............000

We have no collectors. Pay your bill before the 10th and save the discount. If this bill is not paid by..........1912, Gas will be SHUT OFF without further notice.

RATES

MINIMUM CHARGE (No. Discount) 50c..............................

First	10,000 Cu. Feet at 50c,	$..............	Net 45c,	$..............
Next	10,000 Cu. Feet at 45c,	$..............	Net 40c,	$..............
Next	10,000 Cu. Feet at 40c,	$..............	Net 35c,	$..............
Next	70,000 Cu. Feet at 35c,	$..............	Net 30c,	$..............
Next	150,000 Cu. Ft. at .2186,	$..............	Net .1967,	$..............
All Over	250,000 Cu. Ft. at .1472,	$..............	Net .1325,	$..............
	Total Gross	$..............	Total Net,	$..............

Net Rate applies to Bills paid at our Office on or before the 10th of following Month, otherwise Gross Rate will be charged—SAVE YOUR DISCOUNT.

1912

The Above Amount is Net, Discount has been deducted.

Fig. 187—POSTAL CARD GAS BILL FORM
Used when Meters are read monthly.

To **GAS CO., Dr.** SEP 4 - 1915

Office: Erie, Pa.

OFFICE HOURS: 8:30 A. M. to 5 P. M.

State Meter 246 000			
" " 228 000			
To Consumption of 18 000 Cubic Feet Gas @ 32c.			
Less 2c per 1000 cubic feet if paid on or before SEP 4 - 1915	5.76		
	.36	5.40	
	5.40		

Pursuant to advice from Public Service Commission no discount will be allowed on payments received through the mail or otherwise after office hours on date stamped above.

PLEASE BRING OR SEND THIS BILL TO BE RECEIPTED

Fig. 188 POSTAL CARD GAS BILL USED FOR CONTINUOUS METER READING

Office Gas Bill Card—To be used when regular mailing card is lost.

To the FORT WORTH GAS COMPANY, Dr.

1001 Throckmorton Street

OFFICE HOURS:
8 30 a. m. to 5 p. m.

FORT WORTH, TEXAS

Gas by Meter, Month of . . . .

State Present Month 000

State Last Taken 000

Cubic Feet Consumed . . . . . . .000 { Cubic feet Gas at 50c

Received Payment,

FORT WORTH GAS COMPANY

By . . . .

Fig. 189—OFFICE GAS BILL CARD FORM

Notice Requesting Payment of Discount When Remittance Without Discount was Received at Gas Office After the 10th of the Month.

. . . . .191 . . .

Dear Sir:

We have your check for . . . .*in payment of* . . . . *Gas Bill. This is the NET amount due, but as your remittance was not mailed until the* . . . . *inst., you are due the gross amount* $ . . .

Your remittance will be applied on account, leaving a balance due us of $ . . . . *Kindly favor us with your check for balance due.*

FORT WORTH GAS CO.

By . . . .

Fig. 190—DISCOUNT REQUEST FORM

HOUSE FITTER'S AND METER SETTER'S REPORT.

Order No............................ **Bill No.** ....

NAME ....**Location**.. ....**Street**

	Size	Number	Amount		Size	Number	Amount	BURNERS	Size	Number	Amount
Tees				Nipples...........				..................Cook			
"				"				..			
"				"				..			
"				"				...........Heat			
"				"				..			
"				"				..			
"				"				...........Fur.			
Ells				"				..			
"				"				Dampers............			
"				"				" Grate			
"				Keys				Sheet Iron............			
"				Floor Plates......				M. Leads (set).......			
"				Crowfeet..				Dresser Coup			
"				Ext'n Rods.........							
St. Ells				Cocks................				Miscellaneous.........			
"				Glo. Val. Brs.....							
Reducers...........				" " "L.S.				M't'r Covers Wood			
"				" " N.P.				" " Tin...			
Caps..................				" " "L.S.							
"				Ang. " Brass				Expansion Joints....			
Collars..............				" " "L.S.							
"				" " N.P.				Manifold......			
Plugs				" " "L.S.							
"									Feet	In.	
"								Pipe............ $^3/_8$in.			
Bushings..								" .... $^1/_2$in.			
"								" .... $^3/_4$in.			
Lip Unions........				Mixers Glo. Br.				" ....1 in.			
" "				" N.P.				" ....$1^1/_4$in.			
Nipples...........				" Kittg.				" ....$1^1/_2$in.			
"				" Kittg. Slip				" ....2 in.			
"				"				" ....3 in.			
"				"				" ....4 in.			

Fitter..... ....**Hours Labor**............... **Fitter**............................. ...... **Hours Labor** ......

Helper... " " .... **Helper** .... " " ....

Helper... " " .... **Helper**...

Completed......... ....191 **Approved**... .... **Foreman**

Fig. 191 REPORT BLANK FOR LABOR AND MATERIAL USED IN HOUSE PIPING AND METER SETTING JOBS

Order No. ....

.... **191** ...

Service for ....

Approved: .... **Street**

.... **Foreman** **Bill No.** ....

MAIN TO CURB				CURB TO METER			
Description	Size	Number	Amount	Description	Size	Number	Amount
Bushings—Malleable							
" "							
Caps				Caps			
Cock—Service				Cock—Meter			
Collars				Collars			
Couplings—Dresser				Couplings—Dresser			
Curb Boxes							
Ells—Malleable				Ells—Malleable			
" "							
" Street				Ells—Street			
" "							
Expansion Joints				Expansion Joints			
Nipples X				Nipples X			
" X				" X			
" X				" X			
Plugs—Black				Plugs—Black			
" "				" "			
Reducers "				Reducers "			
" "				" "			
Saddles							
Tees—Malleable				Tees—Malleable			
" "				" "			
Union Flange							
Valve—Gate							
	Feet	In.			Feet	In	
Pipe 1 inch				Pipe 1 inch			
Pipe 1¼ inch				Pipe 1¼ inch			
Pipe 1½ inch				Pipe 1½ inch			
Pipe 2 inch				Pipe 2 inch			
Pipe inch				Pipe inch			
Labor	Hours	Rate		Labor	Hours	Rate	
Foreman				Foreman			
Helper				Helper			
Helper				Helper			
Helper				Helper			
Helper				Helper			
Helper				Helper			
Helper				Helper			
Total				Total			

Fig. 192 FOREMAN'S REPORT FOR LABOR AND MATERIAL USED ON INSTALLING SERVICE LINE

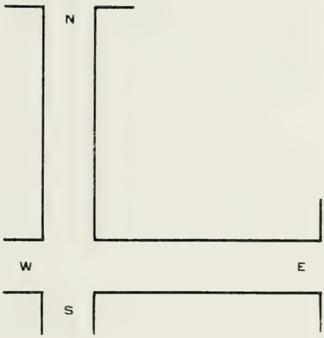


DIAGRAM OF SERVICE LINE REPORT—MAIN TO CURB.

INSTRUCTION:—To complete this Report, lengths and sizes of Pipes are to be clearly indicated in above diagram by drawing a line from the centre of nearest street intersection to the point at which Street Main is tapped, then a line to right angle from this point into the premises

Indicate distances and sizes of the Street Main and Pipe from Main to Curb by figures above the line for distances and below the line for size of Pipe

Fig. 193 REVERSE SIDE OF FOREMAN'S REPORT BLANK, Figure No. 192.

PART THIRTEEN

Domestic Meter

FLAT RATE—INSTALLING METER—METER HOUSE — DISCONNECTING METER — PROVING — REPAIRING METERS — CONTINUOUS METER READING—CAPACITIES—TIN METER PARTS—STANDARD PROVER—CUBIC FOOT BOTTLE—ERRATIC METERS.

Flat Rate System—Changing from a flat rate system to a meter system will result in a saving of from sixty to seventy per cent. of the gas previously consumed. This great difference can be attributed to various causes, principally as follows: On a flat rate system consumers will invariably use cheap, wasteful burners; they will drill out the mixer when the pressure is low in an endeavour to get a larger supply; they pay no attention to turning off the gas when work is finished or the temperature of the house is sufficiently high; and when the temperature does get too high, the tendency is to open the doors and windows in preference to turning down the fire. In fact, fires and lights are left burning night and day. All of these practices do the consumer no good and waste thousands of cubic feet of this ideal fuel. It should be borne in mind that gas is a luxury and should not be wasted.

With a meter installed, it is an easy matter to test piping for leaks by turning off all fires and lights and noting by the small dial whether there is any gas passing through the meter. This is impossible on a flat rate.

With a meter system the life of any gas field will be prolonged several years over a flat rate system.

Domestic Gas Meter—All things considered, the gas meter is the most reliable measuring apparatus made. This may be a startling statement; nevertheless, it is true. If, in a test for accuracy, one hundred of the best watches were compared with one hundred gas meters, for one, two, three or more years, both operating under the same conditions, i. e., exposed to the action of gas, heat, cold, etc., the average registration of one hundred meters would be more accurate than that of the one hundred watches.

The following is a brief description of the tin gas meter shown in Figure Number 198. The diaphragms—two in number—are in the lower part of the meter; the valves and fittings in the upper part. The index registers the quantity of gas delivered by the meter.

The principle of a gas meter can be readily understood. We are all familiar with bellows such as are used at fireplaces. Let us assume a pair of bellows is empty; then that the handles are extended and the bellows filled with air. If the handles are afterwards brought together the air is expelled. If a stop be placed on the bellows, both when closed and when opened, they must make a certain fixed stroke and receive and give out a fixed quantity of air with each motion. The diaphragm of a gas meter does the same thing. It receives a certain fixed quantity of gas and then expels it, having the same stroke every time. By means of the attachments in the meter each stroke is registered and translated into cubic feet on the index, which is a simple piece of geared mechanism by which the cubic feet are recorded by the thousand. In a gas meter there are two diaphragms or bellows, as only one would give an intermittent supply.

The gas meter may also be likened to a steam engine. Steam is admitted through the slide valves of an engine, the valves being of the same kind as are used in gas meters; the piston is pushed forward and a certain amount of steam admitted to the cylinder—the cylinder of the engine corre-

sponding to the diaphragm of the meter. Steam is then taken on the other side of the piston and the piston pushed back again. Each complete stroke requires or takes a given, fixed quantity of steam. Knowing the quantity of each stroke, the steam could be registered in thousands of cubic feet, if it were desired to do so, as gas in a meter.

The steam engine is also similar to the gas meter, in that the steam would rather not work the engine if it could help it. If there should be a leak in the valve, around the piston rings, or elsewhere, the steam would pass out, as it would be easier than pushing the engine. It is a well-known law of physics that fluids will take the path of least resistance. Gas acts the same way in the meter, having a tendency to pass through without working the bellows if it can find any point for leakage. For this reason the general average of gas meters is slow, or against the gas company.

Prepayment, or "slot," meters are regular meters with a mechanical attachment so that coins can be inserted and a proportionate amount of gas purchased. A valve closes gradually, to give warning, when the gas paid for has been consumed.

It is the custom of gas companies to inspect meters regularly and so keep them in good condition. This practice is a protection to both the consumer and the company. Records are kept of the test on each meter, and it is surprising how close the results are. It can be safely said the average net result is slow, or in favor of the consumer, and, at the same time, this average error is less than 2 per cent. It is a fact of public record that the bulk of meters, even when complained of, will show slow registration. Some few meters register fast, owing to occasional derangement of the meter, which it is not possible to avoid with any mechanical appliance; but the total number of fast meters, in proportion to all meters in use, is relatively very insignificant. This can easily be verified from the

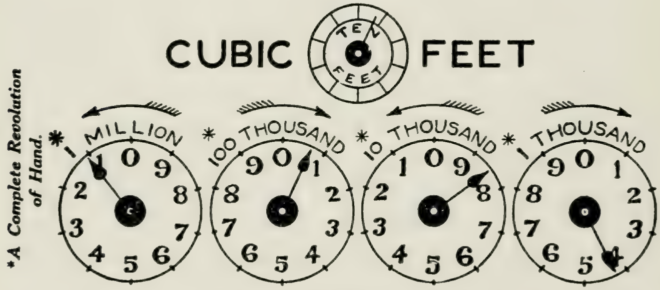
records of city or state meter inspectors anywhere in the United States or throughout the world.

Many people, without thinking about the matter, believe that gas is wrongfully charged to them; this is a mistake. Gas meters are made by manufacturers who specialize in this work, and these manufacturers do not send out incorrect meters; in fact, they take as much professional pride in their product as do the makers of watches or clocks. The workmen who prove the meters are also sworn to let no meter pass if it is not correct. Some law suits have occurred over gas bills, and, after scientific testimony, the meter has been upheld in every case.

There are several reasons to account for the popular distrust of gas meters. One is that very few are familiar with the principle of a meter, and without knowledge of its construction they do not realize that the meter, is a scientific measuring instrument. Another reason is that bills are usually paid after the gas has been consumed. People pay more willingly for what they have on hand yet to be used than they do for material or commodities already used, as in the case with gas. Another reason is that the meter will always deliver gas when called upon and not forget to record it. Very few people remember how many lights have been burned, or how long the gas stove has been used during the month. Dark and cloudy weather causes greater consumption, and in severely cold weather people stay at home and gas heaters are used more frequently and continuously. Other things affect gas bills which, in reality, are under the control of the householder. A dark wall paper, for instance, will absorb light, while a light coloring will reflect it.

Reading a Domestic Gas Meter—A general recognition of the amount of gas burned would be better understood if people would read the registration on the index of their gas meter. The accompanying view represents the ordinary type of index as generally used in gas meters. In reading,

always take the last figure the hand or pointer has passed, and always read the numerals in sequence, beginning with the highest dial on the index. Remember when the pointer is between two figures always take the smaller figure. It is never necessary to reset a meter index. When the finger on the circle of highest denomination has made a complete revolution, all fingers will correspondingly revert to zero, and the entire index will, therefore, automatically reset itself. In reading an index keep a record of the amount of gas consumed, and on taking the next reading deduct the amount of previous reading and the difference will represent the amount of gas consumed in the period between the present and the previous reading of the meter.



TO READ YOUR METER

Each hand moves in a different direction, indicated by the arrows. Read the figure that the hand has actually passed, beginning with the dial to the left—add two ciphers to the right of your figures

DIAL AS ABOVE READS 108,400

Subtract the last month's reading from the present index and the difference will be the gas used to date in cubic feet.

Fig. 194—CONSUMERS INSTRUCTION CARD FOR READING METERS

If in doubt about the accuracy of your meter, ask the gas company to test it, and be present at the test if you wish. The method of testing or proving is simple and easily understood.

Continuous Meter Reading—This system has many advantages in favor of both the consumer and the gas company.

Primarily where gas companies formally required six meter readers to complete the work in the last few days of the month they would need under the new system but one who would be reading meters from twenty to twenty-five days a month. The one reader would naturally become more efficient and less liable to make mistakes, working continuously, than the greater number working but a few days each month.

With the old system it was often necessary to retain men throughout the month even though they had little other work to do, in order to have competent meter readers. This was an unnecessary expense but could not be very well avoided.

It prevents inconvenience to the public by doing away with the "waiting line" at the gas office so common on the 10th of the month.

It does away with the extra clerks necessary to receive the money during the last day of discount under the old system.

There is practically no difference to the consumer as the meter is read on the same date each month.

Capacity of Domestic Meters—The true method of judging the maximum capacity of meters is by determining the amount of gas a meter will pass with a certain intake pressure and a certain discharge pressure while the meter is connected in a service line working under conditions similar to those found in the average house. The average range of low pressure in domestic service is from 4 to 8 ounces, and it is essential to deliver gas to the stove or range at about three ounces pressure. Consequently in selecting the proper size meter, it is good policy to determine

the capacity by what the meter will pass with a four ounce pressure on the intake or inlet and a three ounce pressure on the discharge or outlet.

While one may compare the open flow capacities of different makes of domestic meters, it is impossible to judge the rated capacity under working conditions by this method.

Fig. 195—DOMESTIC METER HOUSE USED BY THE OHIO FUEL SUPPLY CO.

Note the method of sealing.

Open flow capacity means the amount of gas or air a meter will pass under certain intake pressure and with the discharge open into the atmosphere.

Differential Pressure—Is the absorption of gas pressure by the working of the meter while the gas is passing through it.

Installing Domestic Meters—Do not install a domestic meter outside of a building. If it is found necessary to do so, it should be covered with a small box or house especially built for it. A metal box can be constructed so as to permit the use of a seal on the box and connections to the meter. This will decrease the liability of any tampering with the meter. An opening can be made in the metal box so that the dial can be read without removing the box. Fit over this opening a cover or lid similar to that used on tin meters.

The meter should be set in a dry place, preferably on a shelf, with the dial facing away from the wall. In cities having street car service, do not set the meter near any water or artificial gas pipes.

In case gas has previously been used in the building, see that the stop cock or valve back of the meter (inlet side) is shut off; also see that the shelf and meter connections are in good condition.

Turn the gas on at the curb stop cock first.

Go through the house or building and cellar and examine all lines and connections from the meter and see that there are no openings. Do not take the word of anyone in regard to this, but examine them personally. If any connections are found open it is better to cap or plug them at company expense. Then turn the gas through the meter and watch the foot or index hand for five minutes to ascertain whether the lines through the building are tight. If they are not tight, shut off the gas at the street. If they are tight turn on the gas, light the fixtures in the house, making sure that the air is all forced out of the house lines, and that the gas supply is good, and watch the meter to see that it registers. See that there are no unions or connections back of the meter other than the regular meter connections. Test connections and meter for leaks. Take the number and reading of the meter just before you set it.

Meters should be set with the clock box properly sealed and with cap lock boxes on the inlet meter connection.

The gas must not be turned on at the meter under any circumstances when the occupants of the building are not at home.

A meter setter or reader must not enter an occupied house or building which is locked or try to gain admittance with a skeleton key.

Disconnecting Domestic Meter—Examine and find out the number of meters on the service line. Shut off the gas at

the curb and try to light a fire to see if it is shut off. Shut off stop cock back of meter, that is, on the inlet side of the meter. Remove the meter, capping or plugging the end of the service line. Take the number and state of the meter. Great care should be taken in securing the name of maker, size, number and meter reading. Reports must be made out on the premises.

In apartment houses where there is more than one meter and the gas cannot be shut off at the curb, shut the stop-cock back of the meter, plug the opening in the header, and seal the stop cock.

In houses where there is only one meter on a service, the meter must not be removed under any circumstances until after the gas has been shut off at the curb. If, for any reason, the curb stop can not be shut, do not disconnect the meter, but return the "disconnect order" to the shop or office, noting on same, in writing, the reason why curb stop cock cannot be closed. The foreman should see that the curb box or stop is repaired at once and meter removed.

In case a building is being torn down, if the cellar wall is in good condition and is not going to be disturbed, shut off the gas at the curb, and plug or cap the service in the cellar. Where the wall is being disturbed, cut the line and plug the stop cock at the street box until new building is completed. Foreman should keep a record of all buildings torn down and services plugged until they are restored to usual conditions.

All stop cocks on the inlet side of meters should be locked with a stop lock and all inlet meter connections should have a cap lock box.

Street or curb boxes should not be installed without a base. The base prevents the box being jammed onto the service line and injuring it.

Where one or more buildings are supplied from the same connections to a street main, separate stops and curb boxes

should be placed on each line, as nearly in front of the buildings as is possible.

Meter setters or inspectors should not use a light in looking for leaks or making inspections. Use a large-necked bottle with soap suds. Apply suds with a small brush.

Before leaving unfinished street work for the night, the foreman in charge should see that at least two red lanterns are burning at all ditch openings or street obstructions. If the ditch can be closed with an hour's overtime work, it is better to complete the work than to leave.

Repair all leaks on company lines at once. If unable to do so, report to the office in writing as to location and size of leak.

Do not set meters where they are difficult to read or to change. Dials should be set at zero at the meter shop where they can be properly sealed.

Treat domestic consumers in a courteous manner. Give consumers all possible information that will tend to better the conditions of their heating, lighting, or cooking appliances.

Proving Domestic Meters—Prior to proving, the meter should stand in the proving room until it attains the same temperature as that of the room. The writer has known cases where a meter brought into the proving room on a cold winter day and immediately tested was found to be 15 per cent slow, while after it became thoroughly warmed tested O. K.

The method employed is simply that of comparing a known volume of air in the prover with the reading on the small dial of the meter, the air passing through the meter by its own pressure, usually two inches of water. The error allowed is two per cent. fast or slow. To be considered accurate the small dial of the meter must register within two per cent of the volume indicated upon the prover scale.

The water seal in the prover should have the same temperature as the temperature of the room. The meter

should be proved on two volumes; in other words, at two different speeds, and be adjusted so as to register alike on both. For the ordinary house meter these volumes are at the rate of fifty and two hundred and fifty cubic feet per hour.

After proving, the meter should be sealed and a record, giving date of test and proof, should be kept in a book for that purpose.

Fig. 196—HYDRO PNEUMATIC METER TESTER FOR TESTING TIN METERS FOR OUTSIDE LEAKS WITH TWO TO THREE POUNDS PRESSURE

Repairing Domestic Meters—Meters should not be repaired or taken apart unless they are afterward proved on a prover. It requires some experience to properly repair, test and correct a domestic meter.

Tin Meter Repairing—Tin meters should be tested from one to three years after being placed in use, the frequency of the tests depending upon the quality of the gas measured and the work performed.

To repair the meters remove front, back and top plates, examine diaphragms carefully, and clean valve seats and covers with gasolene. If a valve cover rocks, it is probable that a small quantity of gas will pass the meter without registering. In this case, valve covers and seats should be carefully ground, using fine emery paper placed over a small flat-surfaced iron plate.

After the meter has been repaired, and is ready for testing, a test should be made with a small light at the meter outlet to determine if meter will register on a small volume.

Diaphragms in tin meters are tested for leaks with five inches water pressure. The cases are tested with seven inches water pressure. After meters are completed, a test for leaks is made under three pounds pressure, by immersing the meters in water.

In proving tin meters, one and one-half inch water pressure is used where they are to measure artificial gas, and two inches water pressure is used where they are to measure natural gas.

To correct erratic tin meters, move the tangent wrist outward on fast meters and toward the center for slow meters. The distance to move a tangent wrist to correct for one per cent., varies on different sized and different makes of meters.

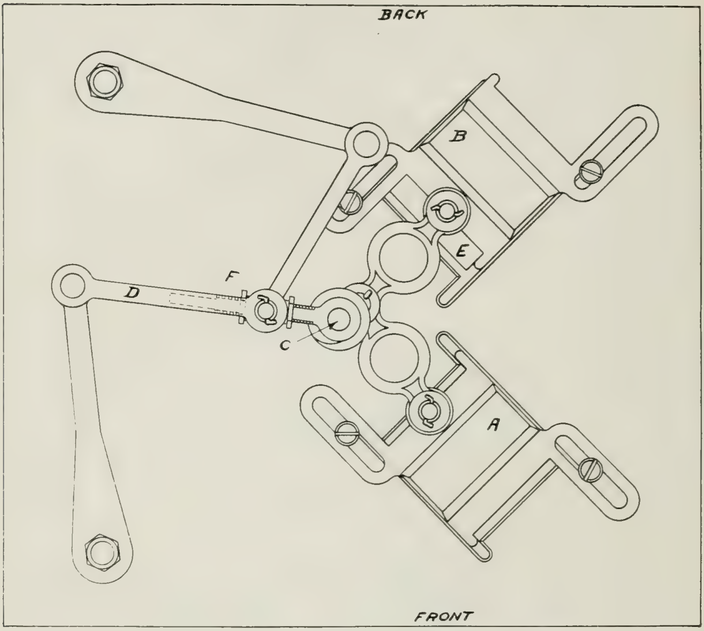


Fig. 197—Top View of Glover Type of Domestic Meter.

Instructions for Setting Valves in Tin or Slide Valve Meter—Set the back valve cover "B" so that the port "E" to the diaphragm is completely open, and the front valve cover "A" is covering both ports of its seat.

Then the tangent "C" should be soldered so that it will be in a straight line with the link "D" as shown at "F".

Above instructions are for right hand meters. For left hand meters reverse the positions of valves A and B.

Diaphragm Oil—Use equal parts of the following oils: greasite, pale meter oil and dark cylinder oil.

Allow diaphragms to soak in the oil thoroughly; then wipe off the excess oil before placing the diaphragms in the meter.

This combination of oils can be used on any standard make of tin or iron meters.

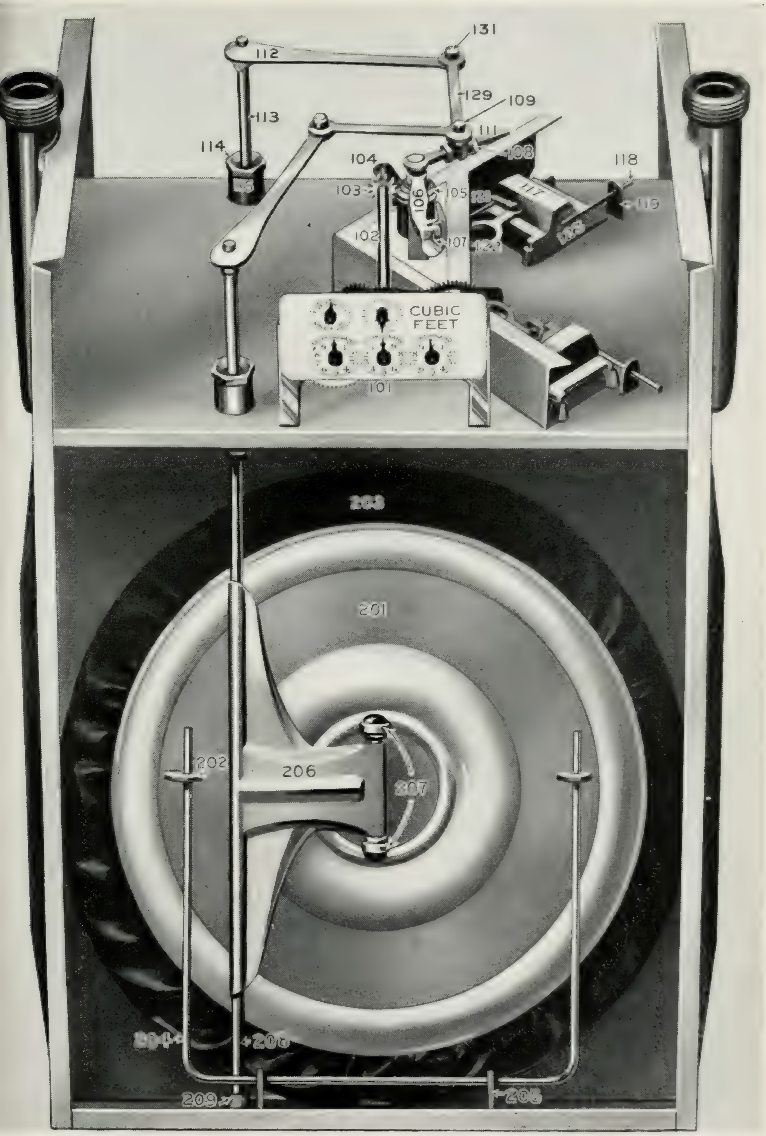


Fig. 198—Interior View of Glover Type Domestic Meter.

LIST OF TIN METER PARTS

Number in Diagram on Page 461

101 Index
102 Axle or Index Shaft
103 Axle Wheel or Index Shaft Wheel
104 Axle Bearing or Index Shaft Rest
105 Worm
106 King Post or Crank Frame
107 Click
*108 Tangent Jamb Nut
*109 Tangent Post or Bat
*110 Tangent Post Pin
*111 Tangent Arm
†112 Long Flag Arm
†129 Short Flag Arm
113 Flag Wire (same as 208)
‡114 Flag Stuffing Box Cap
‡115 Flag Stuffing Box
117 Valve Cover
118 Valve Cover Wire
119 Valve Cover Wire Guide
121 Valve Wrist and Pin
122 Valve Link
123 Valve Seat
129 Short Flag Arm
130 Crank
131 Flag Arm Rivet
132 Crank Stuffing Box
134 Crank Stuffing Box Cap
201 Disc
202 Disc Guide
203 Diaphragm
204 Disc Wire
205 Disc Wire Bracket
§206 Flag
§207 Rock Shaft and Carriage
208 Flag Wire (same as 113)
209 Flag Wire Step

*Parts Nos. 108, 109, 110 and 111, Tangent complete.
†Parts Nos. 112 and 129, Flag Arm complete.
‡Parts Nos. 114 and 115, Flag Stuffing Box complete.
§Parts Nos. 206 and 207, Flag complete.

Rating of Tin Meter Capacities—The first rated capacity of meters was based on the then Standard English Burner, consuming six cubic feet an hour.

Under this rating the hourly capacity of a three-light meter would be 3 x 6, or 18 cubic feet.

A five-light meter, 30 cubic feet, and

A ten-light meter, 60 cubic feet.

Others in proportion.

While the meters as made to-day still have the original rating and are proved under this rating as required by law, it is by no means their actual working capacity, which is now generally determined by the amount of gas which they will pass under a certain differential in pressure, usually five-tenths, with a one and one-half-inch or two-inch water pressure on inlet of meter.

Standard Meter Provers—The meter prover is the standard instrument by which the proof of a meter is ascertained. All meter provers should be calibrated by means of a cubic foot bottle which has been standardized by the Bureau of Standards at Washington, D. C.

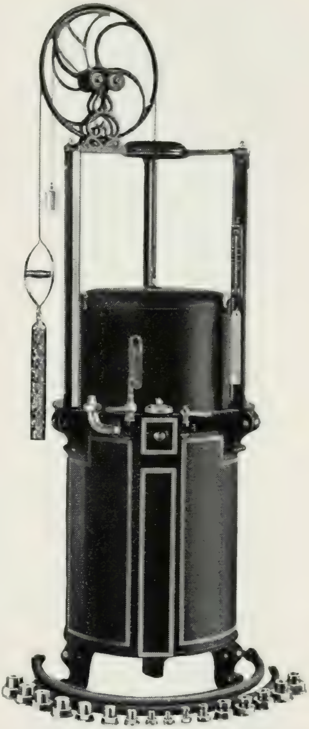


Fig. 199—STANDARD METER PROVER

The meter prover consists of a tank containing water in which is suspended a bell or holder having a supporting chain going over a large balance wheel. At the end of this chain is a weight holder with weights to give the desired gas pressure inside the bell. To the axis of the balance wheel is attached an involute with a counterpoise weight, the purpose of which is to maintain a uniform pressure at all points of travel of the bell. The wheel, chain, involute and weights are supported by a framework consisting of three columns and a triangular bridge across the top of the columns. The bases of the columns are screwed to sockets in the top of the tank.

The bell is guided by three rollers at the bottom and three at the top of the bell.

On the front of the bell is a scale properly graduated in cubic feet and fractions thereof by means of which is ascertained the exact amount of gas or air passed through a meter during its test.

On the front of the body is a channel having at its top a valve and two cocks—right and left-hand. A hose is attached to either one of the cocks, as desired. On the outer end of this hose is a coupling for attaching to the meters to be tested. The connection to the meters is made by using intermediate reducers or increasers called inlet connections, except for one size which the hose coupling will fit, usually the ten-light meter.

Two thermometers are provided for each prover—one to give the temperature of the water and the other that of the air. A six inch siphon gauge is also furnished to give the pressure under which the prover is being operated.

These provers are usually constructed of galvanized iron throughout, either japanned or plainly painted. They are also made with brass tank, or body, japanned, and polished copper bell, this latter form being preferred by many on account of its great durability.

The regular sizes are 2-foot, 5-foot, 10-foot and 20-foot capacity.

Cubic Foot Bottle—This instrument is the basis of all gas measurement. The correctness of any gas measuring device is, in its final analysis, determined by the cubic foot bottle.

It is standardized by the Bureau of Standards at Washington, D. C., and its accuracy is beyond dispute.

The principle that it works on is the simplest of the simple, namely, a volume of one cubic foot of gas being displaced by a volume of one cubic foot of water. The mechanical detail required to do that conveniently and accurately is not so simple.

As can be seen from the illustration, there is a cabinet containing and supporting the cubic foot bottle, its system of piping and its tanks. The bottle, as the copper receptacle in the center of the cabinet is called, has a capacity of one

cubic foot. At its top and bottom are gauge glasses with pointers. When the water rises from the bottom pointer to the top one, one cubic foot of gas has been delivered.

The operation is as follows: The lower tank is filled with water and this water is pumped to the upper tank. All temperatures of water, room and instrument to be tested are equalized. Then close all cocks, open the vent above the bottle and open the cocks that admit the water from the top tank to the bottom of the bottle and allow the water to come to the pointer on the lower gauge glass. At this instant close the lower cock. Then close the vent and open the cocks in the line of piping leading to the article being tested. Then reopen the cock admitting water to the bottle. Allow the water to fill the bottle and to come to the pointer on the upper gauge glass. Close the water cock and the piping cock. Then one cubic foot of air has been delivered. Next open the vent and the cock admitting water to the lower tank and allow the water to drain out of the bottle. Next pump the water from the lower tank to the upper. Then repeat the method of procedure of

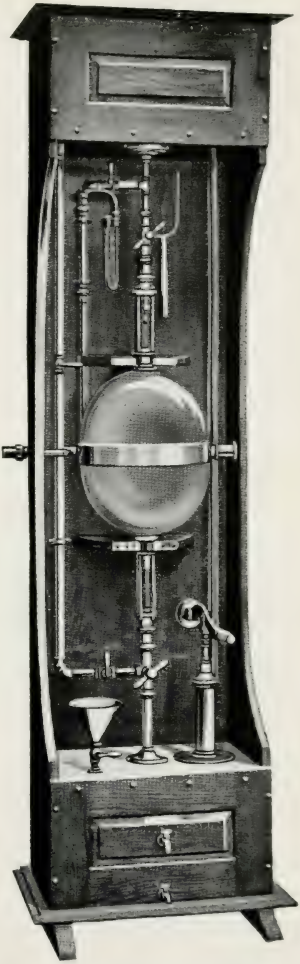


Fig. 200
CUBIC FOOT BOTTLE FOR TESTING PROVERS

operation of the bottle if successive cubic feet are desired. Extreme care must be exercised to always have temperatures exact and unvarying. In some instances the operation must be conducted in a room in which the air is saturated with aqueous vapor.

Correction of Erratic Meters (*By F. H. Oliphant*)—A **fast** meter is one which registers too many cubic feet and a **slow** meter is one which registers too few cubic feet, as compared with a prover which measures the correct number of cubic feet and which is the standard to which all meters are compared.

The multipliers in the following tables are all less than one for **fast** meters and greater than one for **slow** meters.

A meter on which the dial shows 10.5 cubic feet when the prover shows 10 cubic feet is called five per cent. **fast** and must be multiplied by .952 to reduce the quantity to standard. A meter on which the dial shows 9.5 cubic feet when the prover shows 10 cubic feet is called five per cent. **slow** and must be multiplied by 1.053 to bring it up to the standard.

Because the dial of many meters cannot be read as accurately as the scale on the prover, it is preferred in some cases to pass the air or gas through meter and prover until the meter registers 10 cubic feet, then shutting off and reading the prover scale. For this use a second table is introduced which, however, is consistent with the first. This method simplifies the computation for the multiplier, which shows directly from the prover scale, being one-tenth the value of the prover scale reading.

The correction factor or multiplier to correct erratic meters is determined by the following formula:

$$\text{Multiplier} = \frac{\text{Prover Reading}}{\text{Meter Reading}}$$

Example:—Say the reading of a meter is 10.0, while the prover reads 12.5, then the multiplier $\frac{12.5}{10} = 1.25$. Or, say

the prover scale reads 8 when the meter reads 10. Then $\frac{8}{10}$ = .8 is the multiplier.

The formula for determining the percentage that a meter is fast is as follows: $\frac{\text{(Meter Reading — Prover Reading)}}{\text{Prover Reading}} \times 100$ = percentage error fast.

Example:—Say a meter registers 10 cu. ft. while the prover shows 8, $\frac{(10-8) \times 100}{8} = \frac{200}{8} = 25\%$ error fast.

The formula for determining the percentage error of a slow meter is as follows:

$\frac{\text{(Prover Reading — Meter Reading)}}{\text{Prover Reading}} \times 100$ = percentage error slow.

Example:—Say a slow meter registering 10 showed 12.5 cu. ft. on the prover, then $\frac{(12.5\text{-}10) \times 100}{12.5} = \frac{250}{12.5} = 20$ per cent. error slow.

The multipliers for slow and fast meters are determined by the following formulas. Multipliers for meters that are slow $= \frac{100}{100 - \text{per cent slow.}}$ Multipliers for meters that are fast $= \frac{100}{100 + \text{per cent fast.}}$

Example:—Suppose a meter is said to be 20 per cent. slow, how is the correction factor or multiplier to be determined? In this case, the multiplier $= \frac{100}{100 - 20} = \frac{100}{80} =$ 1.25.

On the other hand, suppose a meter is reported 25 per cent. fast. Here the multiplier $= \frac{100}{100 + 25} = \frac{100}{125} = .80$.

Table Giving Multipliers for Correction of Erratic Register of Meters Slow and Fast

Meter Reading Cu. Ft.	Slow Meters			Fast Meters		
	Prover Reading Cu. Ft.	Percentage of Variation (Prover being Standard)	Multipliers to Correct Slow Meters	Prover Reading Cu. Ft.	Percentage of Variation (Prover being Stand'd)	Multipliers to Correct Fast Meters
10	13.7	27.00	1.37	10.0	0.00	1.00
10	13.6	26.47	1.36	9.9	1.01	.99
10	13.5	25.93	1.35	9.8	2.04	.98
10	13.4	25.37	1.34	9.7	3.09	.97
10	13.3	24.81	1.33	9.6	4.17	.96
10	13.2	24.24	1.32	9.5	5.26	.95
10	13.1	23.66	1.31	9.4	6.38	.94
10	13.0	23.08	1.30	9.3	7.53	.93
10	12.9	22.48	1.29	9.2	8.70	.92
10	12.8	21.88	1.28	9.1	9.89	.91
10	12.7	21.26	1.27	9.0	11.11	.90
10	12.6	20.63	1.26	8.9	12.36	.89
10	12.5	20.00	1.25	8.8	13.63	.88
10	12.4	19.35	1.24	8.7	14.94	.87
10	12.3	18.70	1.23	8.6	16.28	.86
10	12.2	18.03	1.22	8.5	17.65	.85
10	12.1	17.35	1.21	8.4	19.05	.84
10	12.0	16.67	1.20	8.3	20.48	.83
10	11.9	15.97	1.19	8.2	21.95	.82
10	11.8	15.26	1.18	8.1	23.46	.81
10	11.7	14.53	1.17	8.0	25.00	.80
10	11.6	13.80	1.16	7.9	26.58	.79
10	11.5	13.04	1.15	7.8	28.20	.78
10	11.4	12.28	1.14	7.7	29.87	.77
10	11.3	11.50	1.13	7.6	31.58	.76
10	11.2	10.71	1.12	7.5	33.33	.75
10	11.1	9.91	1.11	7.4	35.13	.74
10	11.0	9.09	1.10	7.3	37.00	.73
10	10.9	8.26	1.09	7.2	38.88	.72
10	10.8	7.41	1.08	7.1	40.84	.71
10	10.7	6.54	1.07	7.0	42.86	.70
10	10.6	5.66	1.06	6.9	44.93	.69
10	10.5	4.76	1.05	6.8	47.06	.68
10	10.4	3.85	1.04	6.7	49.26	.67
10	10.3	2.91	1.03	6.6	51.51	.66
10	10.2	1.96	1.02	6.5	53.85	.65
10	10.1	0.99	1.01	6.4	56.25	.64
10	10.0	0.00	1.00	6.3	58.73	.63

Examples:—Suppose 10 cubic feet in a meter showed only 7.5 cubic feet in the prover, the meter is 33.33 per cent. **fast.** In the table opposite 7.5, multiplier .75 is found. Say a meter in use recorded 42.250 cubic feet when disconnected and was found to be 33.33 per cent. fast, then 42.250 × .75 = 31,687.5 cubic feet, which is the corrected quantity. On the other hand, if a meter recording 10 cubic feet gave 11.5 cubic feet in the prover, the meter is 13.04 per cent. **slow,** and in the table opposite 11.5 cubic feet a multiplier of 1.15 is recorded. If the meter registered 42.250 cubic feet when disconnected, then 42.250 × 1.15 = 48,587.5 cubic feet is the correct quantity. It will be observed that the multiplier for correcting erratic meters is the quantity recorded by the prover with the decimal point moved one figure to the left. Then if the prover shows 11.5 cubic feet and the meter10 cubic feet, the correcting multiplier is 1.15. On the other hand, if the prover shows 7.5 cubic feet and the meter 10, the correcting multiplier is .75. If the prover should show 10.125 and the meter 10 cubic feet, the multiplier will be 1.0125, etc. It is much more direct to use the multiplier than reduce the percentages to get the corrected quantity from an erratic meter.

Complaint Meter—Figure Number 201 shows a Complaint Meter with top open, and with recording chart in position on drum. This meter is so constructed that its clockwork runs for one week, and when set in the house of a consumer will record on the paper chart of the cylinder the exact amount of gas consumed, marking the hours gas was consumed, either day or night. This makes such a convincing record that the consumer cannot dispute the facts shown, and learns to his own satisfaction that his bills are correct.

On the other hand, should the consumer be positive that no all-night lights are used, and yet the meter records consumption during the night period, it would show practically that there is some house-pipe leakage in the dwelling.

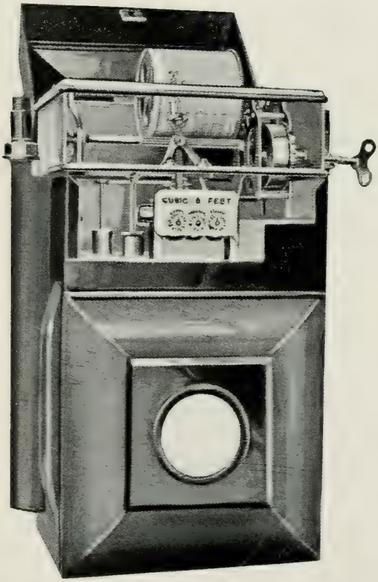


Fig. 201—COMPLAINT METER

The cylinder is so constructed that in its revolution it gradually works on the worm-gear horizontal shaft from one side of the meter to the other, taking the full seven days to complete the run, the small marker shown in front of the cylinder making an absolute record of gas consumed during each hour of that period. These record sheets or charts are detachable from the cylinder, and upon completion of any week's work may be taken off and new charts substituted, making the meter continuous in its operation.

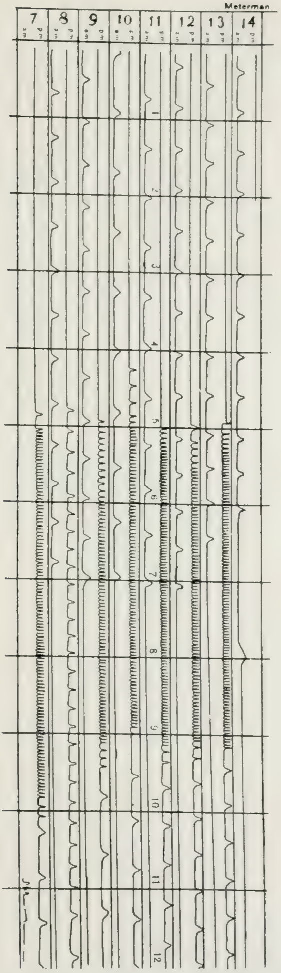


Fig. 202—TAPE OR CHART FROM COMPLAINT METER

In the Figure Number 202 is shown a record taken from a complaint meter after having been through a complete week's run, extending from Monday, the seventh of the month, about 10:55 a. m., until the following Monday, the fourteenth of the month, at about 2:05 p. m. By following the lines drawn by the marker on this chart it is easily seen that the first gas passed through this meter at about 4:50 p. m. on the afternoon of the seventh, the meter maintaining a good average consumption until 10 o'clock in the evening. From that time on the meter showed apparently a slight consumption until 7 o'clock in the morning of the eighth, from which time until 4:45 in the afternoon there was no gas consumed. On the evening of the eighth of the month the family was evidently out for the evening, as very little gas was passed, etc. The history as to further consumption can be readily traced out by the chart through the successive days.

Figure Number 201 shows a five light meter equipped with the complaint device. In this size meter each dash on chart represents two feet of gas passed. In larger sized meters each dash would represent a greater amount of gas passed.

PART FOURTEEN

Domestic Consumption of Gas

High Gas Bills—When a consumer considers his gas-bill too high, before complaining to the gas company, he should test the house piping for leaks. This is very easily done by turning out all fires, lights or hot water burners and watching the small dial on the meter for at least fifteen minutes to see if it registers any gas passing. If the hand on this dial moves it indicates leakage in the house piping.

If small dial registers in 15 minutes	Cubic Feet per month leakage	Loss per month with gas at 30c. per 1000 cubic feet
1 cu. ft.	2,880	$0.86
2 "	5,760	1.73
3 "	8,640	2.59
4 "	11,520	3.46
5 "	14,400	4.32

The small hand or any other hand on the dial will not revolve and register gas unless there is gas passing through the meter.

According to S. S. Wyer (see chart on page 182) of the volume of gas actually delivered to the domestic consumer about 16 per cent. is wasted through leakage on the premises of the consumer and about 36 per cent. through loss in heat energy at the burners. The remainder, or about 47 per cent., represents the percentage of the volume from which the consumer derives full benefit in heat units or energy. In other words, in the average gas bill of any amount—for instance, in a bill for 100,000 cu. ft. of gas for one month only the number of heat units in 47,000 cu. ft. of gas are actually used while the amount of leakage is 16,000 cu. ft.

The yellow flame in a stove burner is a waste of gas and helps to increase the gas bills. There is less heat units in a yellow than in a blue flame. All flames should burn with a blue color tinged with red.

In cooking it is not necessary to leave a burner turned on full head with the flames burning around the sides of a kettle or spider. It is a waste of gas. When through cooking turn off the gas.

Likewise with heating stoves, do not open the doors and windows when the temperature of the room becomes too high. Turn down the gas instead.

The consumer should consider the use of gas the same as he would the use of coal. If he were obliged to purchase gas in quantities the same as he would purchase coal or other fuel, and could from time to time watch the diminishing supply, he would naturally be more economical in its use and less likely to think his gas bills too high.

Is it at all surprising that the consumer should complain? Of course the complaint is made to the gas company as they are the only ones to benefit financially from the sale of the gas, but what control has the gas company over the waste of gas on the consumers premises? They have no more control over the use of gas in one's home than the grocer has over the groceries he sells you. One may purchase a peck of potatoes and waste one half in the paring and of course never think of complaining to the grocer.

It would be far better for the gas company were the consumers to use the gas with reasonable care and economy. It would lessen the individual gas bills, create personal workers for new consumers and naturally increase the sale of gas by the increased number of consumers.

Again, if all leakage in the house piping were stopped it would remove a very expensive liability due to explosion caused by gas from leaks in house piping. Whenever an

explosion occurs it invariably means a law suit and often takes years for the courts to determine whether the leak was on the outside or the inside of the house.

If the consumer would obtain 80 to 90 per cent. efficiency from the gas purchased through the meter, he would have little reason to complain of high gas bills and if practiced generally by gas consumers it would be one great step toward the conservation of our natural gas resources.

Proper Color of Flame in Stove Burners—The proper color of the flame in burners should be blue tinged with red.

It is quite common for the burners and mixers to become dirty when the gas will not properly mix with air. This condition causes a yellow flame.

When this condition exists the burners and mixers should be taken apart and washed clean with hot soap and water, and the mixer should be readjusted till the proper color of flame is obtained.

Fig. 203

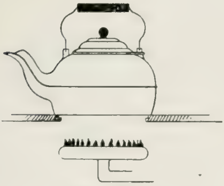


Fig. 204

Fig. 204—A low flame requires more time to boil water but by raising burner, a most economical fire can be maintained. Pressure ½ ounce.

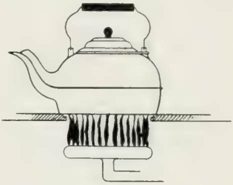


Fig. 205

Fig. 205—The proper size flame for the average gas range. Pressure 2 ounces. Height of flame, 4 inches.

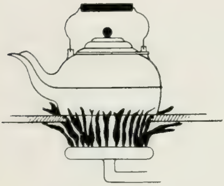


Fig. 206

Fig. 206—Shows gas being wasted. Pressure 5 ounces. Height of flame 10½ inches (measured without kettle over stove hole).

Gas Range Burner Tests—The following tests were made on a modern gas range burner by boiling eight pounds of water with different color flames or mixer adjustments and at different pressures. Temperature of water at start of each test was 70° fahr. and at completion of test 206° fahr. or boiling point. Pressures were taken at the burner.

With yellow flame—

Test No.	Height of flame at center of burner.	Pressure in oz.	Time required.	Cubic feet of gas burned.
1	4 inches	2	20 min.	3.0
2	6½ "	3	17¼ "	3.2
3	8½ "	4	20 "	4.3
4	10½ "	5	21 "	5.

With blue flame—

Test No.	Height of flame at center of burner.	Pressure in oz.	Time required.	Cubic feet of gas
5	4 inches	2	$19\frac{1}{2}$ min.	2.8
6	$6\frac{1}{2}$ "	3	$16\frac{1}{2}$ "	3.
7	$8\frac{1}{2}$ "	4	15 "	3.1
8	$10\frac{1}{2}$ "	5	14 "	3.4

From the foregoing tests it is shown that the most economical use of natural gas is with the 2-ounce pressure and the blue flame.

Lights—Often the mixer and the screen in the burner will become clogged with dust. By removing the mantle the dust can be blown out with one's breath. The screen in the cap directly under the mantle can be removed or blown out. Clean the pin hole through which the gas enters the mixer. A hat pin will be found most convenient for this. Do not increase the size of the hole unless the amount of gas is too small to give a full sized blue flame.

Summary of House Heating Furnace Tests—The following table, showing the result of tests made by Samuel S. Wyer for the Ohio Fuel Supply Company in 1912, gives a summary of experiments made on furnaces which were in no way specially prepared for the tests, and the results represent actual operating conditions in a home. The figures, however, do not consider the cost of handling ashes, damage to home furnishings from coal soot, labor in looking after a solid fuel furnace and the fact that with gas the fuel consumption can be stopped instantly, whereas with solid fuel the fire must be allowed to burn out.

Fuel and Furnace	Cost of Fuel Delivered	Heat Units in Fuel	Heat Units from $1 Worth of Fuel	Fuel Consumption per Hour	Temp. of Smoke deg. fahr.
	Per Cu. Ft.	Per Cu. Ft.		Cu. Ft.	
Natural Gas, special gas furnace.	$0.30	980	2,023,000	83	220
Natural Gas, ordinary natural gas furnace.........	.30	980	1,109,000	156	482
furnace fitted with burner No. 2, 1/8-inch mixers	.30	980	924,000	100	467
Natural gas, coal furnace fitted with burner No. 3, 5/32-inch mixers	.30	980	967,000	100	602
	Per Ton	Per Lb.			
Coke, coal furnace, 19-inch fire pot .	$5.50	13,500	867,000	....	over 1000
Hocking Nut Coal, coal furnace, 19-inch fire-pot. ...	3.25	12,000	987,000	....	over 1000
Pocahontas Nut Coal, coal furnace, 19-inch fire-pot.........	4.50	14,000	1,250,000	....	over 1000

Suggestions for Domestic Consumers—Do not look for a leak with a lighted match or candle. Upon first discovery of a leak open all doors and windows.

A leak in house piping can be temporarily stopped by covering the opening with soap and a bandage. If this is resorted to permanent repairs should be made as quickly as possible.

Sweating on walls in a residence is caused by bad drafts, open top of stove or lack of chimney connection. It is more apt to occur in winter when the houses are kept closed.

There is about ten per cent more moisture in burnt fumes from manufactured gas than from natural gas.

Keep the damper in the stove pipe partially closed according to the amount of fire in the stove. Natural gas does not require a great amount of draft, but what little it does require must be perfect.

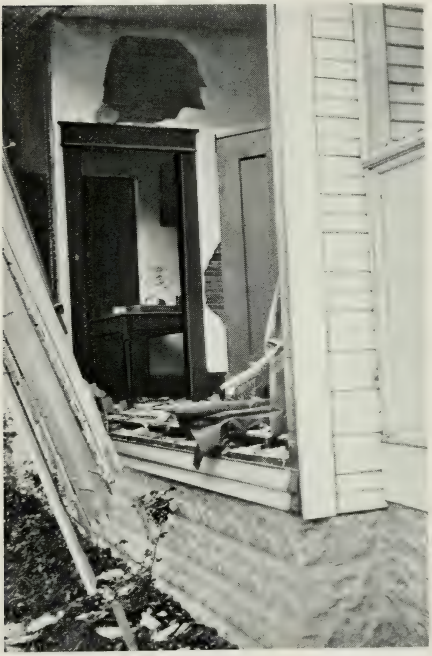


Fig. 207—AN EXPLOSION OF NATURAL GAS IN A PRIVATE HOME INDIRECTLY DUE TO USING RUBBER TUBING FOR STOVE CONNECTIONS

Do not use rubber tubing for connecting gas to heating stoves, hot plates or cook stoves, and for light connections it is allowable only with perfect connections at the burner and the hose cock. When rubber tubing is used for lights use the valve at the gas fixture. Flexible metallic tubing is safer than rubber tubing. A great many asphyxiations and fires have been directly accounted for by rubber hose connections.

Heating or cook stoves should not be used without a chimney connection to carry off the burnt gases.

The effect of burnt gases on the room itself is a condensation of the moisture on the walls or windows, often causing the paper to drop from the walls.

Gas stoves should be placed at a safe distance from the wall, with a sheet of metal underneath.

Domestic consumers should learn to read their own meter and thus be able to verify the correctness of their monthly gas bill. This will also give an apportunity of determining how much gas any particular stove will burn an hour.

Cooking and Heating with Natural Gas When Pressure is Low or a Shortage of Gas Exists—The majority of consumers consider that when the gas pressure is low they are being cheated by the gas company and that a refund should be given. Actually, however, the gas company is the loser. If it had more gas to sell, it would be receiving greater returns during the period of shortage. No gas company desires to have a shortage and invariably does everything in its power to forestall anything of this nature. The efforts put forth by gas companies in this direction are seldom known and rarely appreciated by the consumer. A shortage has never taken place but that the gas company could have sold more gas during the period than it actually had to sell.

The consumer may state that "the gas is low" and that the gas obtained by him is "no good" and has air in it. The first statement is justifiable in case of a shortage, but the latter two are unreasonable though they must be answered with all due politeness and consideration.

The writer has never known of an instance where air has been "pumped" into a gas line, either at high or low pressure, to increase the meter bills. The fact that it is a most dangerous practice is too well known to natural gas men.

Without question, the consumer is getting the same quality of gas, during the shortage, as when the pressure is normal.

It has been proven that with low pressure during a gas shortage (as, for instance, one or two ounces) more actual benefit is received by the consumer per cubic foot of gas than when the pressure is high or normal.

When the fire in a cook stove actually blows or roars, it is a true indication that a full benefit of the heat units in the gas is not being taken advantage of and considerable waste exists.

In a heating stove practically the same number of heat units per cubic foot of gas are obtained when the pressure is low as when the pressure is high or normal.

The consumer can state honestly that he is not getting enough gas for his wants, but as to the quality of the gas being different or poor, this is a mistaken idea.

It should be borne in mind by the consumer that during exceptionally cold weather, when shortages are likely to take place, natural gas is a luxury given us by nature and is not simply a case of "put on more coal" to increase the supply.

Comparison of Domestic Meter Bills by the Consumer—Distributing companies commonly receive complaints from patrons that their friends, neighbors or acquaintances with smaller homes, fewer people in the family, and with extravagant appliances, have smaller bills.

First, make sure that the meter is accurate, either by looking up the record and learning that the meter in question has lately been tested, or by making a special test. Then carefully and politely take up the comparison of grocery or other household bills. It will be found that they will not foot up the same. The number of rooms in a house has as little to do with the gas bill as the number of people in the family has to do with the grocery bill. No two families are alike with regard to their home wants and requirements.

It might be added that it is just as reasonable for the gas man to sell gas by the stove or flat rate as it is for the grocery man to contract to supply groceries for a home by the number of persons in it.

Water Condensation from Burnt Gases (*By Professor Haworth*)—"When burned, one volume of methane (the main constituent of natural gas) unites with two volumes of oxygen, which is equivalent to ten volumes of air.

The products of combustion are two volumes of water vapor and one volume of carbon dioxide. The production of water vapor becomes apparent in the combustion of natural gas, the water vapor condensing and collecting on any cold object near the burning gas. This gives rise to the popular belief that the gas as it comes in the pipes is wet or loaded with water. A simple calculation will show us the remarkably large amount of water produced in the burning of 1000 cubic feet of methane.

Each 1000 cubic feet of methane produces on combustion twice its own volume or 2000 cubic feet of water vapor. This weighs 100.13 lb. and is equal to approximately 12 U. S. gallons of liquid water. Now if we have a natural gas containing ninety-five per cent. of pure methane, it would give ninety-five per cent. as much water per 1000 cubic feet, that is 95 lb. or 11.4 gallons.

This shows that the production of a large quantity of water is an inevitable accompaniment of the combustion of natural gas, and it is no evidence of a good or a bad quality of gas itself, excepting that the quantity of water thus produced increases as the percentage of methane in the gas increases. It therefore should be considered a sign of good quality instead of bad. The heat of combustion of methane is 1003 B. t. u. per cubic foot of gas."

Incandescent Light Mantles—The original research work in the invention of the incandescent light mantle was begun by Carl Auer von Welsbach in 1880 at the Bunson Laboratory at the University of Heidelburg.

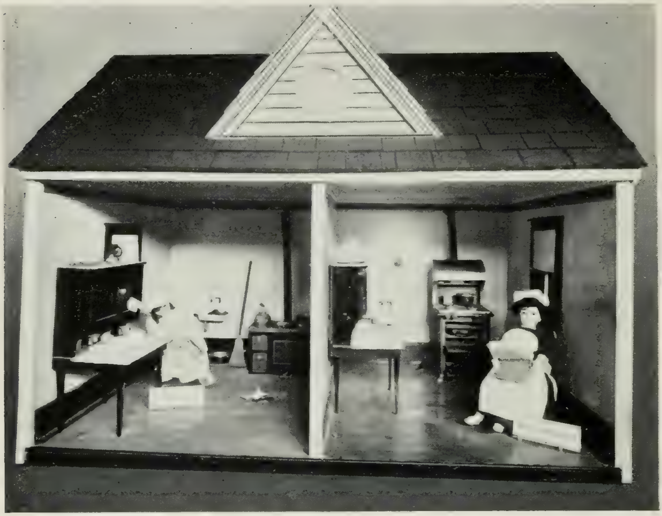


Fig. 208—A GAS OFFICE WINDOW DISPLAY
Depicting the "Before" and "After" by the Introduction of Natural Gas.

Not until 1890 did this young man bring the invention to a successful standard. The preparation consisted of 1 per cent. cerium and 99 per cent. thorium. The cerium is responsible for the high luminous effect.

Artificial fibre, cotton, and ramie thread are used to support the coating of cerium and thorium. The cotton and ramie thread are hollow while the artificial fibre is like a solid rod. The shrinkage of mantles is generally due to the cotton or ramie thread collapsing after burning.

Before using, the mantles must be burnt off, leaving the "ash" of the original make-up, this ash being the real light producer.

PART FIFTEEN

Industrial Consumption of Gas

COMPARATIVE FUEL VALUE—FACTS AND FIGURES ABOUT NATURAL GAS USED IN VARIOUS INDUSTRIES — BOILER INSTALLATION (*Section*)—GAS ENGINE (*Section*)—POWER (*Section*).

Comparative Fuel Value of Coal, Oil and Natural Gas—Good practice, with boilers of proper construction and proportioned to the work:

1 lb. of coal will evaporate 9 lb. of water from and at 212 deg. fahr.

1 lb. of oil will evaporate 13 lb. of water from and at 212 deg. fahr.

1 lb. of natural gas will evaporate 15 lb. of water from and at 212 deg. fahr.

1 lb. of coal will equal 12 cu. ft. of natural gas.

1 ton of coal (2000 lb.) will equal 24,000 cu. ft. of natural gas.

1 lb. of oil will equal 17 cu. ft. of natural gas.

1 bbl. (42 gal.) will equal 5,000 cu. ft. of natural gas.

5 bbl. (42 gal.) will equal 1 ton of good coal.

1 cu. ft. of natural gas will evaporate 0.75 lb. of water.

1 cu. ft. of natural gas contains 990 B. t. u. gross.

1000 cu. ft. of natural gas contains 990,000 B. t. u.

1 ton of coal contains 28,000,000 B. t. u.

1 bbl. of oil contains 5,600,000 B. t. u.

1 bbl. of oil 41 deg. gravity, weight 287.5, U.S. bbl., contains 5.615 cu. ft.

1 cu. ft. of water at 39.8 deg. fahr. at 30 inches of mercury, atmospheric pressure, weighs 62.42 lb.

Under fair conditions a 100 h. p. boiler will use about 4000 lb. of R. M. bituminous coal in ten hours.

In the foregoing values only good quality coal, gas and oil are considered. Natural gas varies greatly in B. t. u. tests from 748 B. t. u. to 1100 B. t. u. 990 is a good average quality.

The quality of coal with reference to B. t. u. varies greatly in different mines and commonly in the same mine.

It should be borne in mind that in the use of coal there is always a waste of fuel in starting the fire under a boiler and after the work is finished. With gas or oil for fuel, less time is required in starting the fire, and after the work is completed the fire can be put out immediately.

Facts and Figures about Natural Gas as Used in Various Industries.

Electricity—Cost of installation per h. p. of an electric plant, in which electricity is developed by steam—$60 to $70 per h. p. and where gas engine is used $80 per h. p.

The amount of gas required in making electricity with steam installation, using gas for fuel, is 40 cu. ft. per kilowatt hour. With a gas engine the amount of gas required for making electricity is about 18 cu. ft. per kilowatt hour.

Cement—The amount of gas required to make one barrel of cement, in plants of more than 1000 barrels daily capacity, is 3000 cu. ft. For the burning only of one barrel of cement in kilns, 1750 cu. ft. of gas is required.

Smelter—The amount of gas required in a smelter to burn one block of 640 retorts for twenty-four hours is between 600,000 and 700,000 cu. ft. of gas, dependent on the kind of ore smelted. In plants of three blocks or more, it is generally figured 1,000,000 cu. ft. of gas is required for each block, which figures include roasting, pottery, and boiler use.

Brick—The amount of gas required in making one thousand brick is as follows:

For burning	12,000 cu. ft.
For drying	1,700 cu. ft.
For steam	1,900 cu. ft.
Total	15,600 cu. ft.

Carbon Black—The manufacture of carbon black from natural gas has become an extensive industry through the gas fields of West Virginia. Invariably the factories are located in gas fields in remote sections and away from any thickly settled districts or cities. While the use of natural gas for this purpose has been criticised on account of the small financial return per thousand cu. ft. of gas, consideration must be given to the fact that if the same gas were piped to a market and a larger gross income received the actual profit would not be much different from that obtained from making carbon black.

It takes about fifteen hundred cubic feet of gas to make one pound of carbon black, and the factories usually operate twenty-four hours a day.

Generally a carbon black factory consists of a row of low, sheet iron buildings in which are long rows of troughs. Under these troughs the gas is burned through common jet burners, the combustion taking place with an insufficient supply of air, resulting in a heavy deposit of unconsumed carbon, or soot, on the under side of the troughs. This soot, or carbon black, is then scraped off and packed in twelve-and-one-half pound bags, which in turn are barreled for shipment.

In this process no use is made of the heat energy of the gas, other than that required to separate the carbon from the hydrogen and other constituents, and it is therefore very wasteful.

BOILER BURNER INSTALLATION (Section)

Boiler Burners for Natural Gas—The secret of success in the use of gas burners under boilers is to thoroughly mix the proper amount of air and gas before these factors reach the point of ignition.

Complete combustion requires the union, under high temperature, of one atom of carbon to two atoms of oxygen. The combustion of one pound of carbon, when supplied and thoroughly mixed with the above amount of oxygen, will produce 14,500 B. t. u.; while one pound of carbon, when supplied with half the above amount of oxygen, will produce only about 4500 B. t. u. In the first case the resulting product of combustion is carbon dioxide, CO_2, and in the second, carbon monoxide, CO.

It is very important that the gas and oxygen be thoroughly mixed after they have been brought together, as the completeness of combustion obtained will depend upon the manner in which they have been mixed. A perfect mixture can be obtained only by putting gas and oxygen in violent agitation before reaching the combustion chamber, for even though the proper proportion of oxygen be present, it may not have a chance to reach all of the carbon atoms to unite with them before the gases pass out of the combustion chamber and become chilled below the temperature of ignition. For this reason it is also necessary to supply more air than is theoretically required for complete combustion.

Temperature of Natural Gas Combustion—Natural Gas combustion, when supplied with the exact amount of air necessary for complete combustion, should burn at a temperature of about 4200 deg. fahr. On account of the excess of air that is necessary for dilution, however, the actual temperature of combustion is about 2200 deg. fahr. It is not always desirable to use an extremely high temperature, as in some cases it would injure the products of the furnace

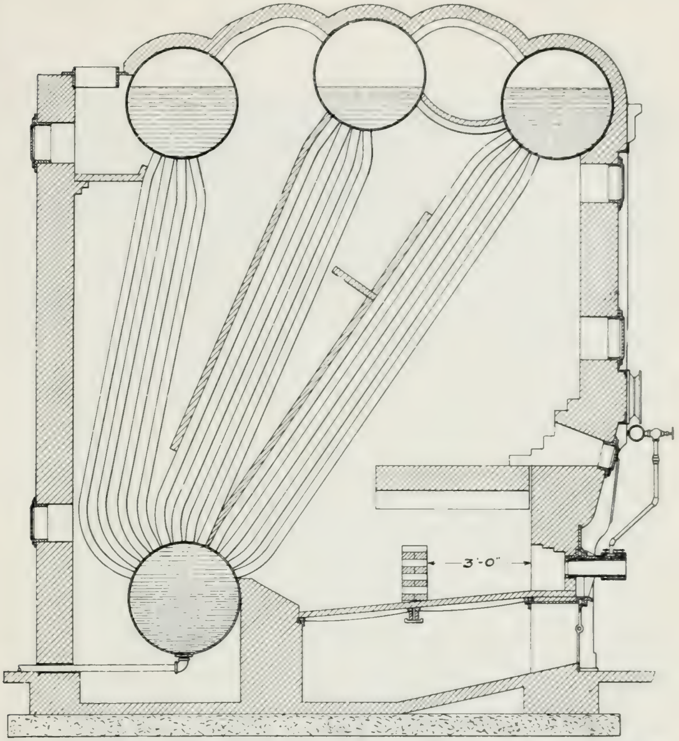


Fig. 209—NATURAL GAS INSTALLATION UNDER WATER TUBE BOILERS

in which it is being used. This would apply to the burning of brick or any other material which is placed in a kiln, and fired after the setting is completed. For this purpose the temperature should be very low when started, and gradually increased as the kiln is heated. When combustion of gas takes place, much moisture is liberated in the form of vapor, which will be condensed on the surface of any object which is at a low temperature and will be absorbed by any object which will retain moisture. This is objectionable for some purposes.

Fig. 210—NATURAL GAS INSTALLATION WITH AUXILIARY OIL BURNER SYSTEM
Installed by the Little Rock Gas & Fuel Co. for the Little Rock Railway and Electric Co., Little Rock, Ark.

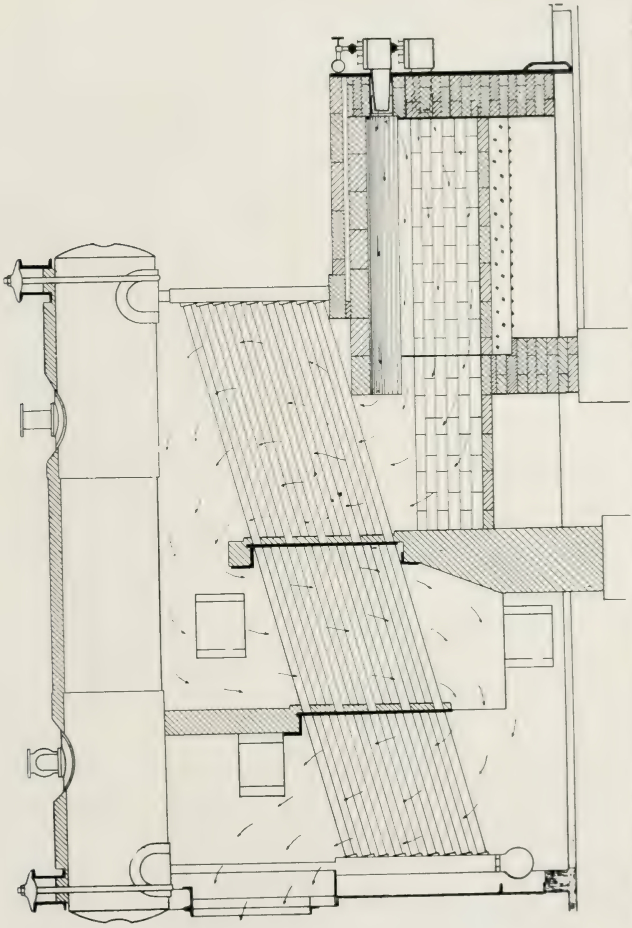


Fig. 211—NATURAL GAS INSTALLATION UNDER MURPHY OR SIMILAR TYPE OF BOILERS

Installation of Natural Gas Burners Under Boilers—While there can be a great many different methods employed in installing natural gas burners under boilers, they all vary but slightly from each other. In covering this subject, we

are making some general suggestions as adopted by gas burner experts.

Cover the entire grate surface (or bottom of furnace if grates are not used) with fire brick or any material that will stand a high temperature, for the purpose of excluding all air and to protect the grates from the heat of the furnace.

Primarily it must be borne in mind that the greatest success with natural gas under boilers is to burn all the combustible with the proper mixture of air.

Place the burners under the fire doors or through holes cut in the front of the furnace as shown in cuts. If burners are placed through the doors, the opening around the burners should be built up with brick and mortar. The burners should not extend beyond this brick wall.

The distance from the end of the burners to the checker-wall will vary under different conditions. Checker-walls should be nine inches thick, and where a three-foot or higher wall is required the thickness should be increased at the bottom and tapered off towards the top. If the wall is not increased in thickness at the bottom, it will not be apt to stand long where it is three feet high or over. A space of one or two inches should always be left at each end of the wall where it joins the side wall to the furnace.

These two spaces are for the purpose of allowing expansion and contraction, which would be liable to throw the wall down unless provided for as above specified.

The height of the wall will depend upon the construction of the furnace, the purpose for which it is being used, and the amount of gas to be consumed. If it is to be used in a boiler furnace and it is desired to work the boiler at or above its rating, care should be taken that the wall is not built up too close to the boiler, as the heat generated will be intense if confined too much in front of the furnace by reason of the checker-wall being built too high or the openings too small.

The object of the checker-wall is to retard slightly the velocity of the burning gas in order to obtain greater benefit where needed, rather than to have the burning gas pass quickly into the hood and stack, spreading the effects of the heat en route.

Should the work the boiler is required to do be light, and at no time exceed the rating of the boiler, the checker-wall can be built with smaller openings and closer to the boiler with better results. In case the draft is very poor and not sufficient for the amount of work being done, a second checker-wall, placed about one foot back of the first, will give better results. If the second wall is used, some air should be admitted from the bottom of the furnace between the two checker-walls.

In a furnace covered by an arch and entirely surrounded with fire-brick, a small amount of checker-wall will be sufficient. In many cases none is required, as the heat generated will be all the furnace will stand without any checker-wall.

As all furnaces are not alike, it is impossible to give instructions that will cover every case. Therefore, any wall or combination of walls that will give the best results is the proper thing to use in that particular case.

In a boiler with a horizontal baffle, where the gases pass to the rear of the furnace, the checker-wall should be about thirty inches from the front wall of the furnace. In selecting the proper size header for a boiler setting, we would suggest the following formula by Gwynn:

$$A = \sqrt{B \times C}$$

A = Diameter of pipe in inches.

B = Area of gas connection to burner.

C = Number of burners used.

Example—It is proposed to install ten five-inch gas burners with one-and-one-half-inch gas connections; what size header would be required? A one-and-one-half-inch gas pipe equals 2.036 in area. As ten burners are to be fed from

this header, the area required would be the area of gas connection to burner, multiplied by the number of burners to be used. In applying these figures to the above formula, the result would be about a five-inch pipe, which would be the smallest size pipe used in this case.

A valve should be placed in the header at the side of the boiler for the purpose of regulating the volume of gas supplied to all burners at one time.

Continue away from header with a gas line of the same size. If this line extends more than twenty or thirty feet, a larger size should be used, as the gas pressure will decrease very rapidly in a long line, especially if there are many turns.

Use of Steam or Compressed Air in Boiler Burner Installations—In very few cases the use of steam in connection with boiler burners is a benefit. In all of such cases some of the following conditions will be present: insufficient draft to carry away the products of combustion; insufficient burner capacity; insufficient boiler or furnace capacity to do the work required; insufficient gas pressure at the burner; installations not properly made; burners not operated in the proper manner. Any or all of these conditions might be present at the same time. When steam is used it is only for the purpose of forcing the proper mixture between the gas and air when this cannot be done in any other manner. This is accomplished by the steam entering the mixing chamber under the same pressure through several very small jets with a spiral or rotary motion and causing a partial vacuum in the air tube, which, in turn, causes the air to flow into the burner and become thoroughly mixed with the gas before reaching the point of ignition. Compressed air may be used for this purpose with much better results, as the only loss will be the power required to compress the air.

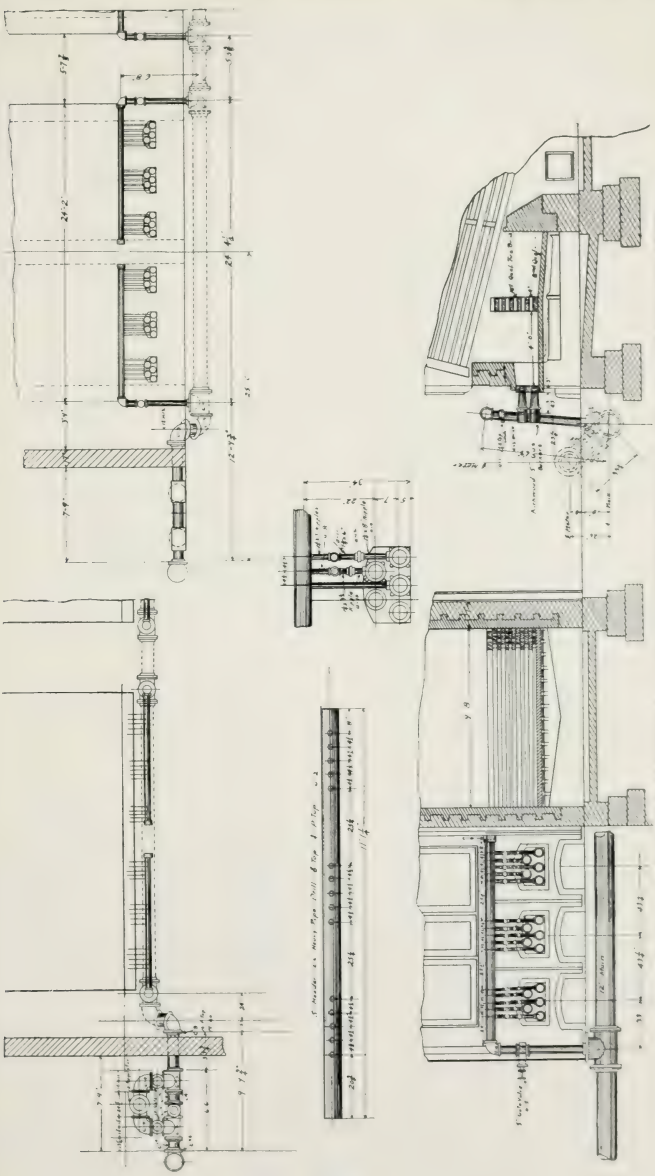


Fig. 212—PLAN OF NATURAL GAS BURNER INSTALLATION UNDER BOILER
(See Detailed List of Specifications on Opposite Page)

FITTINGS ON GAS MAIN

Symbol	
C-1	5 12-inch Cast Iron Flanged Tees, faced and drilled.
C-2	2 10-inch Cast Iron Flanged Tees, faced and drilled.
C-3	3 12-inch Cast Iron Flanged Ells, faced and drilled.
C-4	2 10-inch Cast Iron Flanged Ells, faced and drilled.
C-5	3 10-inch Cast Iron Flanged Gate Valves.
C-6	12 12-inch Cast Iron Flanges faced and drilled.
C-7	6 5-inch Cast Iron Flanges, faced and drilled (5-inch pipe tap, outside diameter 19 inches).
C-8	1 10-inch Cast Iron Flange, faced and drilled (10-inch pipe tap, outside diameter 19 inches).
C-9	5 10-inch Cast Iron Flanges, faced and drilled, (10-inch pipe tap, outside diameter 16 inches).
C-10	3 12-inch Wrought Iron Pipes (threaded), about 22 feet 4 inches long.
C-11	2 12-inch Wrought Iron pipes (threaded), about 3 feet 5 inches long.
C-12	1 12-inch Wrought Iron Nipple, (threaded), about 10 inches long.
C-13	1 10-inch Wrought Iron Nipple (threaded).
C-14	1 10-inch Wrought Iron Nipple.
C-15	1 10-inch Wrought Iron Pipe, about 3 feet 3¾ inches long.

BILL OF MATERIAL FOR ONE BOILER

Symbol	
A-1	15 5-inch Gas Burners.
A-2	1 5-inch Wrought Iron Header.
A-3	1 5-inch Cast Iron Cap.
A-4	1 5-inch Cast Iron Ell.
A-5	1 5-inch Cast Iron Gate Valve.
A-6	1 5-inch Wrought Iron Long Nipple, 12 inches long.
A-7	1 5-inch Wrought Iron Pipe (threaded), about 3 feet 10 inches long.
A-8	15 1¼-inch Wrought Iron Long Nipples, 6 inches long.
A-9	9 1¼-inch Wrought Iron Long Nipples, 8 inches long.
A-10	12 1¼-inch Wrought Iron Long Nipples, 3½ inches long.
A-11	15 1¼-inch Cast Iron Stop Cocks.
A-12	15 1¼-inch Malleable Iron Dart Unions.
A-13	9 1¼-inch Nipples, 6 inches long.
B-1	242 9-inch Fire Brick, to cover grates. (Use second quality.)
B-2	232 9-inch Fire Bricks, for checker wall. (Use Benezet.)
B-3	10 9x4½x1¼-inch Fire Brick Splits, for filling doors.
B-4	1 Sack Fire Clay.

The use of steam in a gas-fired furnace is always attended with a loss, as the heat absorbed by the reduction of one pound of steam to hydrogen and oxygen is much greater

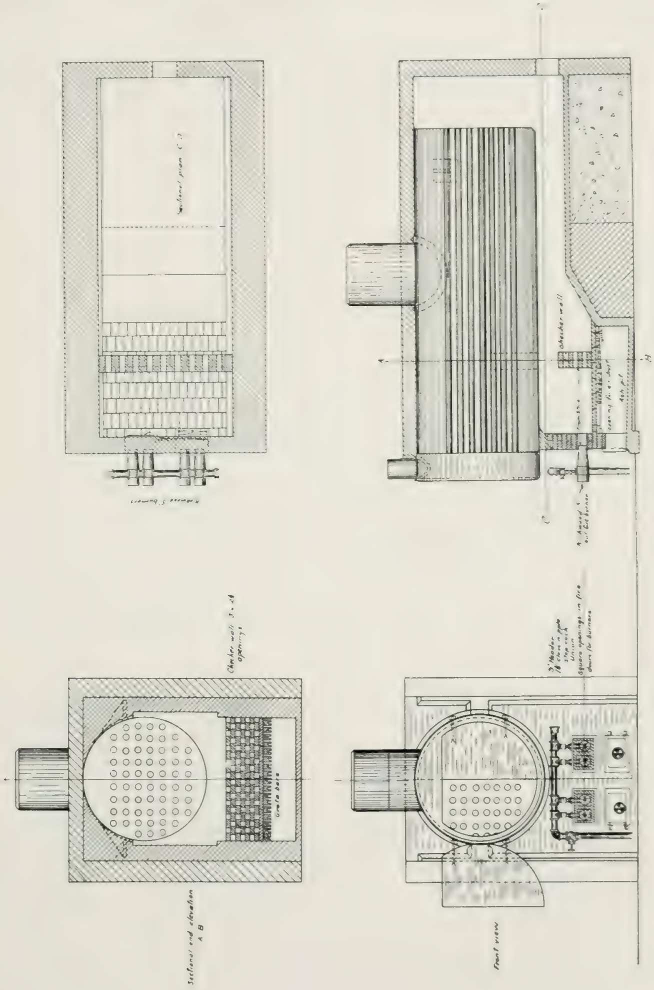


Fig. 213

in amount than the heat generated by the union with the carbon of oxygen thus set free. This loss may be partially recovered if the furnace is kept at the proper temperature to quickly reduce the steam to hydrogen, which will be consumed with the gas.

Draft—In lighting a furnace which has been closed down, care should be used to see that the damper is open and that there is enough draft to carry away the products of combustion; otherwise, the flame will soon be extinguished and the escaping gas may cause trouble if re-ignited. Any serious obstruction to the draft while boiler or furnace is in operation might have the same effect.

A very simple method of increasing the economy of the burning of gas under a boiler, whether an analysis of stack gas is made or not, is to use a screw damper in connection with a common siphon gauge to measure the stack draft. As a rule the screw damper is a home-made affair designed to regulate the draft and carry continually a suction or minus pressure in the stack as shown on the gauge. A common four-inch siphon gauge should be located in close proximity to the damper regulator or screw and the damper regulated according to the pressure. The screw attachment on the damper permits of delicate and careful regulation of the damper opening.

The best suction pressure or draft to carry must be determined by actual tests. After once determined it should be checked by subsequent tests two or three times a year. To make this test the screw damper and gauge must be installed first and a certain stack pressure carried on the gauge continuously during the entire length of each individual test.

It is a well known fact that changes in atmospheric conditions such as barometer, temperature and humidity greatly affect the draft in any chimney or stack. With the

screw damper and siphon gauge, an even stack pressure best suited to the boiler conditions can be carried at all times.

A special draft gauge will indicate the suction or minus pressure more closely than the common siphon gauge but is a more expensive instrument.

Generally the draft of medium sized stacks or chimneys will be about one or two-tenths water pressure.

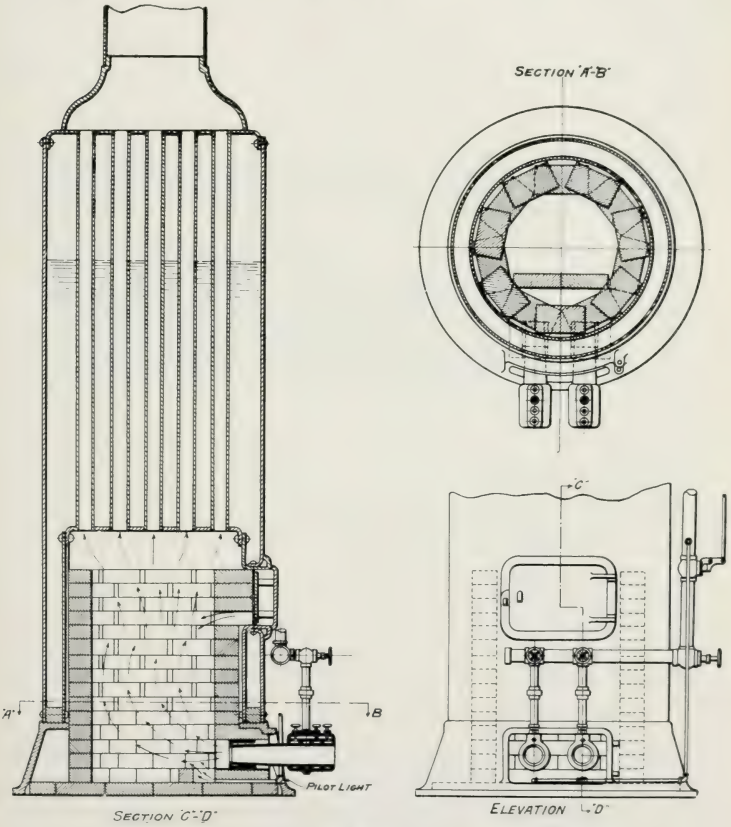


Fig. 214
NATURAL GAS BURNERS AS APPLIED TO VERTICAL TUBULAR BOILERS

Draft Gauge—The draft gauge is a modification of the ordinary U tube gauge, one of the tubes being expanded in a reservoir and the other inclined at an angle to the latter, the angle of inclination being in accordance with the desired length of the scale. This lengthens each one inch of vertical scale into a scale five or ten inches long as desired, and thus 1-100 of an inch pressure on the differential gauge is as easily determined and read as 1-10 of an inch on the ordinary gauge.

The fluid employed for filling is the oil known as "Mineral Seal," having a specific gravity 39 to 40 Beaume, and is

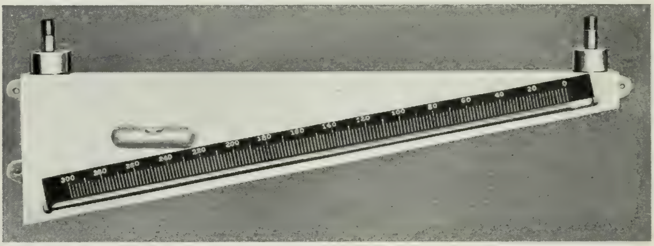


Fig. 215—DRAFT GAUGE

preferable to water because its capillary attraction is much less, thus producing more accurate indications. The evaporation is also much less than water.

The instrument is made of an aluminum casting, finely finished or of finely finished wood. It is portable and readily adjustable to position.

Connections are tapped for one-eighth-inch gas pipe.

Made in one-inch and three-inch sizes.

Operation of Natural Gas Burners for Boiler Use—In addition to careful installation, the success of a gas burner depends somewhat on the manner in which it is operated. After the installation has been completed and the burners are ready to put in operation, see that all the valves of the

gas line leading to the burners are closed, also that the damper in the stack is open enough to carry away the product of combustion. A torch can be lighted and placed through the center of a burner or through an opening beside it before gas is turned on to this individual burner. When one burner has been lighted the others can be turned on, one at a time, each igniting from the preceding one; or if too far apart each will have to be lighted as was the first one.

Under no consideration should a gas valve be opened until the light has been put into the furnace, as enough gas will accumulate in the furnace in a few seconds to do some damage if lighted suddenly. After burners have all been put in operation, see that there is sufficient draft to carry away the products of combustion. Where there have been just two or three burners used and the checker-walls have become "white heat" and the burners have either accidentally been turned off or gone out, the lighted torch should be placed in the furnace to ignite the gas before a burner is turned on again. It should not be expected that gas will ignite from the white heated checker-wall. Actual ignition is apt to be delayed until considerable gas has accumulated in the furnace, thereby causing a dangerous explosion. Under no circumstances, in case the gas flame goes out, should one depend upon the white heated checker-wall to ignite the gas.

When the furnace is cold it should be heated up slowly, as it might damage the brick work if heated too rapidly. Only enough burners should be used to do the work required, as their economy will be better when they are worked at their full rating.

Gas should not be used at a greater pressure than ten or twelve ounces. Results will not be so satisfactory as if used at a lower pressure. Satisfactory results have been obtained on small installations with burners as low as one-half ounce pressure.

A good draft is absolutely essential, especially if the furnace is working at a high rating, and should always be maintained.

A gas-fired furnace should burn with a clear blue flame and white heat and with as little white flame as possible. The presence of white flame indicates carbon monoxide, (CO), which means bad combustion.

As no two boilers or furnaces will work exactly alike, no positive instructions can be given which will cover all cases. The object, however, is to secure as nearly perfect combustion as possible. Therefore, any valve or combination of valves or other conditions which will obtain that result are the proper ones to use, regardless of any other instructions.

SOME CAUSES RESPONSIBLE FOR FAILURES WITH NATURAL GAS BURNERS

Leak of gas supply at burner.

Pipes too small and too many turns.

Pipes clogged by corrosion or other foreign matter.

Burner openings clogged with dirt.

Burner capacity too small for work it does.

Draft not sufficient for work being done.

Burners not properly installed.

Burners not properly operated.

It is not probable that all these defects will be present in any one case, but some of the above defects will be found to exist where failures result.

Boiler Testing—There have been many cases where boiler tests have shown a great loss of fuel through improper mixture of gas and air in the burner. Although the cost of the boiler test is rather expensive, and though it may not show any possibilities of saving fuel, it is a great satisfaction to the interested party to learn whether they are obtaining the full benefit from the gas.

In making a boiler test where natural gas is used as fuel in a patent burner, the following suggestions should be followed: Prior to making test the boiler should be thoroughly examined and should be absolutely free from any scale. The area of the heating surface should be figured next, using the diameter of the tube next to the water. The surface below the mean level of the water is termed as a rule, "water heating surface," and the surface above the mean level of the water is called "super-heating surface."

Install new or lately tested gas and water meters, using a low pressure regulator back of gas meter to enable the carrying of an even pressure of gas. In laying out the gas line it should be provided with a mercury gauge and a thermometer well to obtain the pressure and the temperature of the gas. Inasmuch as the temperature of the feed water should be kept as high as possible in order to get the maximum efficiency from the gas, it is necessary to use a hot water meter. If a feed pump is used, the meter should work on the boiler side of the pump and the working pressure of the pump be kept as constant as possible. If an injector is used on the water line feeding the boiler, it should receive the steam directly from the boiler while being tested, and the feed water should be passed through the hot water meter after being thrown out by the injector.

Prior to starting test, the boiler should be heated up for at least three or four hours and put into service on the main steam line. A test should last from ten to twenty-four hours and a log sheet kept of all meter readings, temperatures, drafts and steam pressures. All notations should be made hourly or oftener. The reading of gas and water meters should be taken at the beginning and every twenty minutes thereafter to the end of the test.

At the time of starting a test the level of the water should be marked on the gauge glass by scratching with a file or tying a piece of wire or string around the glass.

Temperatures should be taken of the steam, feed water, stack, and gas and air in the engine room and outside of the building.

The draft should be measured with water in a U tube both in the furnace and the hood of the stack. The steam pressure and gas pressure should be noted hourly. Any heavy or sudden pull on the boiler should be mentioned under the head of "Remarks."

The test should be absolutely uniform with respect to load to get the conditions of maximum economy, but to show the sensitiveness of the burner and boiler, a variable load should be used.

A calorimeter test is important to ascertain the quality of the steam, i.e., whether the steam is "saturated" or contains the quantity of heat due to the pressure according to standard experiments; second, whether the quantity of heat is deficient, causing the steam to be wet; and third, whether the heat is in excess and the steam superheated.

The method commonly employed is the barrel calorimeter, which with careful operation and fairly accurate instruments may generally be relied upon to give results within two per cent.

The calorimeter is described as follows: A sample of steam is taken by inserting a perforated one-half-inch pipe into and through the main pipe near the boiler and conducted by a hose, thoroughly felted, to a barrel holding preferably 400 pounds of water, which is set upon a platform scale provided with a valve for allowing the water to flow to waste and with a small propeller for stirring the water.

The barrel is filled with water, the weight and temperature ascertained, steam blown through the hose outside the barrel until the pipe is thoroughly warm, when the hose is suddenly thrust into the water and the propeller operated until the temperature of the water is increased to a desired

point, usually about 110 deg. The hose is then withdrawn quickly, the temperature noted, and the weight again taken.

An error of one-tenth pound in weighing the condensed steam or an error of one-half degree in temperature will cause an error of over one per cent. in the calculated percentage of moisture.

The calculation of the percentage of moisture is made as follows (Kent's "Mechanical Engineer's Book"):

$$Q = \frac{1}{H - T}\left[\frac{W}{w} = (h_1 - h) - (T - h_1)\right]$$

Q = Quality of steam, dry saturated steam being unity.

H = Total heat of one pound of steam at the observed pressure.

T = Total heat of one pound of water at the temperature of steam of observed pressure.

h = Total heat of one pound of condensing water, original.

h_1 = Total heat of one pound of condensing water, final.

W = Weight of condensing water corrected for water-equivalent of the apparatus.

w = Weight of the steam condensed.

Percentage of moisture = $1 - Q$.

If Q is greater than unity, the steam is superheated, and the degrees of superheating equal 2.0833 $(H - T)(Q - 1)$.

For accurate determination, all the steam made by the boiler should be passed through a separator, the water separated should be weighed, and a calorimeter test made of the steam just after it has passed the separator. The percentage of water extracted by the separator should then be added to that determined by the calorimeter to give the total percentage of mixture in the steam.

The throttling calorimeter is a convenient and accurate instrument for determining the quality of the steam. For description, see any treatise on boiler or boiler testing.

The analysis of gas to be used, while not always required, is necessary for an exhaustive test, and from this analysis the calorific value of the fuel can be calculated; or, better still, this value may be directly determined by some standard form of calorimeter, such as the Junker's.

A chemical analysis of the stack gas should be carefully made by a chemist to determine the existence of unburnt gases caused by improper mixture of gas and air in the burner. Samples of stack gas should be taken hourly and the analysis can be made by the common Orsat apparatus to show the carbon dioxide, carbon monoxide, oxygen and nitrogen. From these results the excess of air used by the burner can be calculated. (See Stack Gas Analysis, following page.)

The method for calculating the boiler efficiency is as follows: Divide the heat absorbed per hundred feet of gas by the calorific value of one hundred cubic feet of gas supplied. From the results obtained from the log sheet, the approximate heat balance or statement of the distribution of heating value of the gas may be obtained.

The gas per hour should be calculated, together with the gas per square foot of heating surface per hour. The total weight of water feed can be calculated from the meter readings, and the feed water temperature by referring to any table which gives the weight per cubic foot of water under different temperatures. The equivalent water fed to the boiler from and at 212 deg. fahr. may be ascertained from a table of factors of evaporation, after having been corrected for moisture in the steam.

The horse power which is determined at 34½ pounds of water evaporated from and at 212 deg. fahr. may be figured from the last results. The builder's rated horse power is

obtained from the boiler specifications and the percentage of boiler's rated horse power calculated.

One boiler horse power is the evaporation of 34½ pounds of water per hour from a feed water temperature of 212 deg. fahr., to steam at the same temperature (spoken of as "from and at 212 deg. fahr.") and is equal to 33,305 B. t. u. per hour.

Testing Gas Burners—The only fair way of testing a gas burner is to analyze the flue gases, a sample of which should be taken as near the point of combustion as possible, having all air leaks well stopped in the boiler setting back of the flue box. The amount of CO, CO_2 and free oxygen contained in this sample will determine whether the right quantities of gas and oxygen were properly mixed at the point of ignition.

Stack Gas Analysis—To every boiler user this branch of engine room work is very important. In fact it is more so than is generally realized. Very few, if any, factories where natural gas is used as fuel are equipped with gas analysis apparatus. The writer does not desire to state that the analyzing of stack gas will show a loss in every case; but where no loss is shown it is a great satisfaction to know that fuel gas is being used with economy.

Sampling Apparatus—A glass tube five-eighth-inch in diameter and about three feet long, drawn down to one-fourth-inch at one end, is inserted in the stack just above the hood. For this purpose a three-quarter-inch hole is drilled in the stack and the space around the glass tube is stopped with putty or wet cotton waste. Prior to taking the sample, all openings other than legitimate ones for draft should be carefully closed.

The stack gas must be sucked into the tube by use of a pump or steam jet. When samples are taken infrequently an ordinary double-ended syringe bulb, provided with a hard rubber valve, may be used.

There are many methods that may be devised, but the main thing to bear in mind is to obtain a true sample of the stack gas absolutely free from air.

The principle of making an analysis is the same as in analyzing natural gas (see page 80), i.e., by absorbing the different constituents in the stack gas sample one by one, and measuring the decrease in volume caused by such absorption.

The following chemical solutions are used for the absorption process.

For carbon dioxide (carbonic acid), potassium hydrate.

For oxygen, alkaline solution of potassium pyrogallate.

For carbonic oxide, cuprous chloride.

After the sample has been subjected to the absorption action of each of the above chemicals and correct deductions made, the residue may consist of nitrogen (the principle constituent), hydrocarbons and hydrogen.

If desired, a sample of the flue gas can be taken—leaving as little water in the apparatus as possible—and sent to a competent chemist for analysis.

Gas Pressure—Pressure should be measured at the burner, not at the meter or regulator. The greater the gas pressure, the greater the velocity of the gas leaving the burner, creating a better vacuum and thereby causing a greater volume of air to enter the mixing chamber, which will increase the capacity of the burner.

Eight-ounce pressure gives the best results, with a working range of from five to twelve ounces.

Results—It is not possible to derive the same boiler efficiency in all gas fields, but assuming that the gas contains 1000 B. t. u. per cubic foot, the boiler or furnace should develop an efficiency of at least seventy per cent. or greater.

BOILER TEST OF NATURAL GAS

Made by Jay M. Whitham at Parsons Pulp & Paper Company, Parsons, W.Va., on Six 250 Horse Power Cook Vertical Water Tube Boilers.

Analysis of Gases Used and Taken from Nine Wells in Lewis County, West Virginia—

	Sample No. 1	Sample No. 2	Sample No. 3
Illuminants	0.45	0.15	0.50
Carbonic oxide	0.00	0.00	0.15
Hydrogen	0.20	0.30	0.25
Marsh gas	81.05	83.20	83.40
Ethane	17.60	15.55	15.40
Carbonic acid	0.00	0.20	0.00
Oxygen	0.15	0.10	0.00
Nitrogen	0.55	0.50	0.30
B. t. u. in a cubic foot of gas at 60 deg. fahr. and 14.7 lb. barometer available for useful effect	1030	1020	1025

Test number	812
Duration, hours	9
Barometer, pounds	14.25
Boiler gauge pressure, pounds	132.7
Draft in front of damper, inches	0.20
Gas pressure at meter, pounds	18.0
Gas pressure at burners, ounces	6.4
Temperature of air, deg. fahr	69
Fire room, deg. fahr	73
Natural gas, deg. fahr	70
Feed water, deg. fahr	185
Chimney, deg. fahr	494
Gas, metered cubic feet	541,420
Equivalent gas at 70 deg. fahr. and under 4 ounces pressure	537,197
Water evaporated, pounds	435,625
Equivalent water at and from 212 deg. fahr., pounds	467,948
Boiler h. p. made	1507.0
Cubic feet of gas, actual, per boiler h. p. per hour	39.92
Cubic feet of gas at 4 ounces and 60 deg. fahr. per boiler h. p. per hour	39.6

GAS ENGINES (Section)

Gas engines are divided into two general classes commonly known as two cycle and four cycle.

These terms are derived from the number of strokes of the piston required to complete a cycle, during which time only one impulse is given to the piston.

The two cycle engine gives one impulse to the piston for each revolution of the crank shaft and is more flexible in speed control than the four cycle engine which gives but one impulse to the piston for each two revolutions of the crank shaft.

For steady work such as driving a pumping station the four cycle engine is best suited.

For fluctuating work such as cleaning out wells the two cycle engine is most desirable.

Ignition is usually effected by allowing the compressed mixture to enter an iron tube, kept at a bright red heat by a Bunsen flame surrounding it. Electric ignition is frequently used, in which case the electric current is generally furnished by a magneto so arranged to generate a maximum current at the proper firing instant.

The proper firing instant varies according to load, speed and quantity of mixture. The length of the hot tube may be varied to suit local conditions.

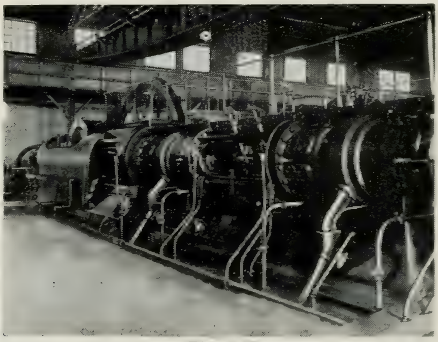


Fig. 216

Average Amount of Natural Gas Required to Operate Gas Engines or for Steam Engines where Natural Gas is used as Fuel Under Boilers, in Cubic Feet per Indicated H. P. per Hour.

Type of Engine	Cubic Feet of Gas per Horse Power per Hour
Large natural gas engine, highest type..........	9
Ordinary natural gas engine....................	13
Triple expansion condensing steam engine......	16
Double expansion condensing steam engine.....	20
Single cylinder and cut-off steam engine........	40
Ordinary high pressure, without cut-off, steam engine....................................	80
Ordinary oil well pumping steam engine........	130

From ten to twelve cubic feet of air are necessary for the complete combustion of one cubic foot of natural gas. The natural gas engine has been most successfully introduced as a source of power throughout the entire gas belt. The first engines were from ten to fifteen horse power, and were used in pumping oil wells. Of late they have also been used to some extent for drilling wells. Many natural gas engines working up to 2,500 horse power, are in use at this date compressing natural gas, where the original pressure is not sufficient to carry the required quantity to market.

Horse Power of Gas Engines—The horse power of a gas engine is usually rated as the actual power delivered to the belt on average fuel. This power delivered to the belt bears a close relationship to the power developed in the cylinder and the more excellent the design and construction of the engine the more nearly will these two powers be equal.

Power is developed by compressing a mixed charge of gas and air in the cylinder and then igniting it. The heat produced by the combustion causes the gases to expand and

exert a pressure on the piston which drives the latter forward to the end of its stroke when the pressure is released by means of the exhaust valve.

The pressure due to rapid combustion is the same for any size engine provided the compression and mixture are the same and the horse power of the engine depends upon the size of the cylinder.

Various ratings are used to designate the size of an engine but the surest guide to comparative power is to compare the sizes of cylinders.

Size for size a two cycle engine will develop something less than twice the power of a four cycle engine.

In buying engines, do not be guided altogether by horse power rating but look well into cylinder sizes to determine whether the engine is large enough to justify its rating.

Size of Gas Supply Pipe—Multiply the horse power of the engine by .03 and add 3/4-inch to find the proper size of gas supply pipe.

Length and Diameter of Services for Gas Engines.

Horse Power of Engine	50 Feet of Pipe Diam. In.	100 Feet of Pipe Diam. In.	150 Feet of Pipe Diam. In.	225 Feet of Pipe Diam. In.
5	1	1	1 1/4	1 1/4
10	1 1/4	1 1/2	1 1/2	1 1/2
15	1 1/4	2	2	2
20	1 1/2	2	2	2
30	1 1/2	2 1/2	2 1/2	2 1/2
40	2	2 1/2	2 1/2	3
50	2 1/2	2 1/2	3	3

Exhaust Pipe—The exhaust pipe should be as straight and free from bends as possible also the outlet should be shielded to prevent rain collecting therein. The diameter of the exhaust pipe should be between one-third and one-quarter of the cylinder diameter.

Circulating Water—Water must be kept circulating in the jacket of the engine cylinder to cool the walls and make lubrication possible. This requires from four to six gallons per horse power per hour. Where a tank is used its capacity should be such as to allow twenty to forty gallons per horse power.

The water circulating pipes should be free from bends and the top or return pipe should be one-half-inch larger than the bottom or inlet pipe. The return pipe should enter the tank below the top level of the water therein.

When hard water is used for the jacket put a handful of ordinary washing soda into the tank about once a month.

COMPARATIVE ACTUAL OPERATING COSTS OF 100 H. P. IN THE VARIOUS PRACTICAL FORMS OF POWER NOW AVAILABLE

Based on a Running Day of 10 Hours; 310 Days per Year; *Full Load* Continuously for Entire Ten Hours.

In making comparisons with his own actual costs of operation, the power user should take the total cost of a single horse power, as given in synopsis below; and, figuring from the basis of the **actual** load his power plant is carrying, cut from, or add to, all the other figures proportionately.

Steam engines are sold at their **indicated** horse power, which is from 10 per cent. to 18 per cent. higher than their brake horse power. Gas engines are sold at **brake** horse power, and a 100 h. p. gas engine has from 10 per cent. to 18 per cent. greater efficiency than a 100 h. p. steam engine.

	Ordinary Steam Engine	Compound Condensing Engine	Electricity
Fuel	1 $3,720.00	2 $2,092.50	3 $6,975.00
Attendance	7 775.00	7 775.00	8 77.50
Oil, waste, cleaning materials	75.00	75.00	50.00
Packing	5.00	5.00	....
Water	11 77.50	387.50	....
Repairs	13 109.50	13 175.50	14 52.50
Depreciation	17 255.50	17 409.50	18 175.00
Interest on investment—6%	219.00	351.00	105.00
Complete actual cost of operation	$5,236.50	$4,271.00	$7,435.00

	Gas Engine Illuminating Gas	Gas Engine Natural Gas	Gas Engine Producer Gas
Fuel	4 $4,216.00	5$ 1,116.00	6 $ 639.37
Attendance	9 155.00	9 155.00	10 258.33
Oil, waste, cleaning materials	75.00	75.00	75.00
Packing	....	....	....
Water	12 46.50	12 46.50	77.50
Repairs	15 75.00	15 75.00	16 85.00
Depreciation	19 187.50	19 187.50	20 187.50
Interest on investment—6%	225.00	225.00	381.00
Complete actual cost of operation	$4,980.00	$1,880.00	$1,703.70

1. Based on 8 lb. coal, at $3 per ton, per B. h. p. hour; covering operation and stand by consumption.

2. Based on 4½ lb. coal, at $3 per ton, per B. h. p. hour; covering operation and standby consumption.

3. 1000 Watts equal 1 Kilowatt; 100 h. p. equals 75 Kilowatts; 75 Kilowatts at 3c per hour equals $22.50 per day.

4. Based on consumption of 17 cubic feet per B. h. p. hour at 80c per M equals $13.60 per day.

5. Based on consumption of 12 cubic feet per B. h. p. hour, at 30c per M equals $3.60 per day.

6. Based on 1.5 anthracite screenings, at $2.50 per ton, per B. h. p. hour, including stand-by losses, equals 1,650 lb. per day.

7. One licensed engineer at $2.50 per day.

8. Average of one hour's attendance per day of man at $2.50.

9. 2 hours per day will cover all attendance necessary; licensed engineer not obligatory.

10. One-third of one man's time, at $2.50 per day, will take care of plant.

11. Based on price of 5c per M. gals., which is about same when pumped by condenser pump.

12. 3 gals. per B. h. p. per hour. By use of tank same water can be used over and over, and water expenses eliminated.

13. Estimated at 3 per cent. of entire cost of plant per annum, including boiler.

14. Estimated at 3 per cent. of entire cost of plant per annum.

15. Estimated at 2 per cent. of entire cost of plant per annum.

16. $10.00 per annum will more than cover all repairs on producer plant, as same is subject to no stress or strain; 2 per cent. is estimated as repairs on gas engine poriton of plant.

17. Estimated at 7 per cent. of entire cost of plant.

18. Estimated at 10 per cent. of entire cost of plant.

19. Estimated at 3 per cent. of entire cost of plant.

20. $10.00 per annum in repairs will keep producer portion of plant in perpetual good condition, and depreciation is therefore figured on gas engine only.

Synopsis of Above Tables of Actual Operating Costs of 100 Horse Power.

	Comparative annual operating costs of 100 h. p. in proportion to initial cost of plant	Actual annual operating cost of different forms of power per h. p.
Ordinary steam engine	143%	$52.36
Compound steam engine	73%	42.71
Electricity	424%	74.35
Illuminating gas	132%	49.80
Natural gas	46%	16.94
Producer gas	24%	14.90

Compounded Steam Engine is 29 per cent. cheaper to operate than an ordinary steam engine.

Electricity is 30 per cent. dearer to operate than an ordinary steam engine.

Gas engine (illum. gas) is 5 per cent. cheaper to operate than an ordinary steam engine.

Gas engine (natural gas) is 68 per cent. cheaper to operate than an ordinary steam engine.

Gas engine (producer gas) is 73 per cent. cheaper to operate than an ordinary steam engine.

Electricity is 43 per cent. dearer to operate than a compound steam engine.

Gas engine (illuminating gas) is 16 per cent. dearer to operate than a compound steam engine.

Gas engine (natural gas) is 61 per cent. cheaper to operate than a compound steam engine.

Gas engine (producer gas) is 65 per cent. cheaper to operate than a compound steam engine.

Gas engine (illuminating gas) is 33 per cent. cheaper to operate than electricity.

Gas engine (natural gas) is 77 per cent. cheaper to operate than electricity.

Gas engine (producer gas) is 80 per cent. cheaper to operate than electricity.

Gas engine (natural gas) is 62 per cent. cheaper to operate than illuminating gas.

Gas engine (producer gas) is 70 per cent. cheaper to operate than illuminating gas.

Gas engine (producer gas) is 12 per cent. cheaper to operate than natural gas.

(*Courtesy Bessemer Gas Engine Co.*)

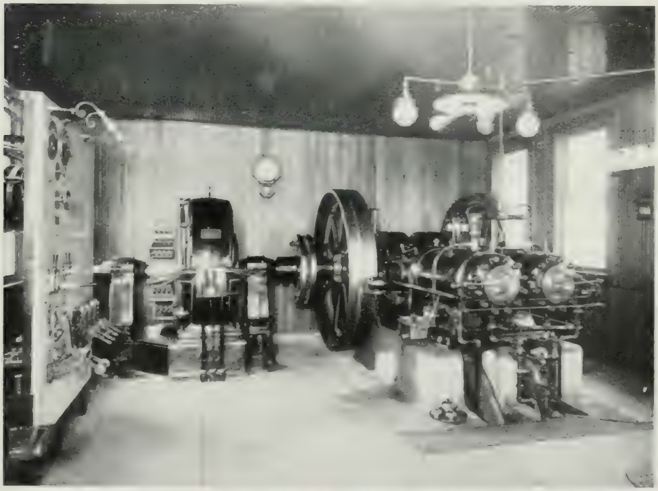


Fig. 217—100 H. P. GAS ENGINE WITH DIRECT CONNECTION TO 100 K. W. GENERATOR

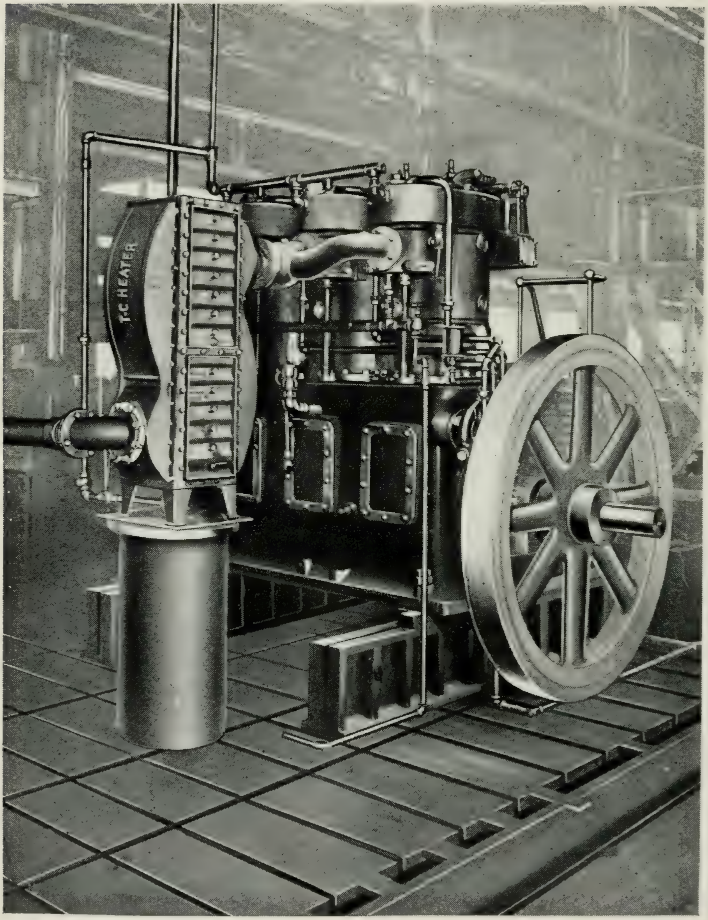


Fig. 218—TRANSVERSE CURRENT HEATER INSTALLED WITH A 100 H. P. GAS ENGINE

Transverse Current Heater for Gas Engines—It is a well known fact that in the use of gas for power in a gas engine but a small percentage of the total B. t. u. in the gas is used. Some engineers claim this to be but 25% and that the balance of the heat units in the gas are wasted in the exhaust or burnt gas from the engine.

The transverse heater is attached to the exhaust pipe of any gas engine and the exhaust gas, in passing through and around the water coils within the heater, as illustrated in Figure Number 219, heats a volume of flowing water. This hot water is mainly valuable for heating although it is used for other purposes. After the heater is once installed there is practically no further expense.

The heater is especially adapted where gas engines or compressors are in use twenty-four hours daily.

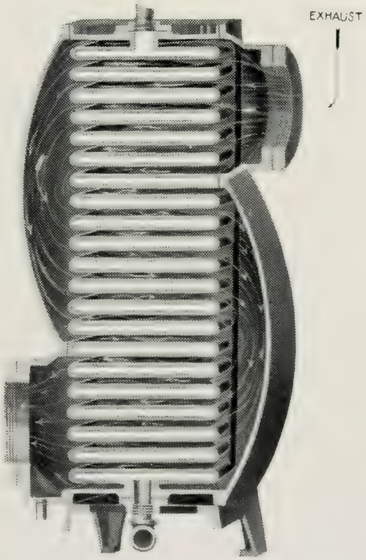


Fig. 219—SECTIONAL VIEW OF TRANSVERSE HEATER.

TABLE No. 1

TABLES SHOWING EFFICIENCY OF TRANSVERSE CURRENT HEATER

Based on Tests Showing H. P. of Gas Engine, Number and Sq. Ft. of Heater Required to Heat Given Quantities of Water per Hour to Any Temperature

Half Load

Engine h. p.	No. of Heater	Sq. Ft. of Heater	Amount of Water in Lb. Heated in One Hour from both Exhaust and Jackets					Amount of Water Heated in One Hour from Exhaust only					B. t. u. Absorbed	
			150°	180°	190°	200°	210°	150°	180°	190°	200°	210°	From Jackets& Exhaust	From Exhaust only
			Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.		
10	1	17	560	430	400	375	350	210	160	150	140	130	56320	21120
25	2	25	1400	1075	1000	885	825	525	400	375	350	325	140800	52800
50	4	50	2800	2150	2000	1775	1650	1050	800	750	700	650	281600	105600
75	5	67	4200	3225	3000	2660	2475	1575	1200	1125	1050	975	422400	158400
100	7	100	5600	4300	4000	3550	3300	2100	1600	1500	1400	1300	563200	211200
150	8	134	8400	6450	6000	5325	4950	3150	2400	2250	2100	1950	844800	316800
200	10	200	11200	8600	8000	7100	6600	4200	3200	3000	2800	2600	1126400	422400
250	11	267	14400	10750	10000	8875	8250	5250	4000	3750	3500	3250	1408000	528000
300	12	333	16800	12900	12000	10650	9900	6300	4800	4500	4200	3900	1689600	633600

For a 500 h. p. engine, multiply figures given in table for 250 h. p. by 2, and for 1000 h. p. engine, multiply figures for 300 h. p. by $3\frac{1}{3}$.

To reduce to gallons, divide pounds of water by 8.3.

To find number of pounds of coal required to heat the same quantity of water under a boiler to same temperature in one hour, divide the B. t. u. absorbed by 7200, which will show economy effected by Heater. *(Courtesy Williams Tool Co.)*

TABLE No. 2

Table Based on Foregoing Tests Showing H. P. of Gas Engine, Number and Sq. Ft. of Heater Required to Heat Given Quantities of Water per Hour to Any Temperature.

Full Load

Engine h. p.	No. of Heater	Sq. ft. of Heater	Amount of Water in Lb. Heated in One Hour from both Exhaust and Jackets					Amount of Water Heated in One Hour from Exhaust only					B. t. u. Absorbed	
			150°	180°	190°	200°	210°	150°	180°	190°	200°	210°	From Jackets & Exhaust	From Exhaust only
			Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.		
10	1	17	873	670	620	580	545	365	280	260	245	220	87380	36710
25	2	25	2180	1675	1550	1470	1360	910	700	650	610	550	218540	91775
50	4	50	4365	3350	3100	2940	2725	1825	1400	1300	1225	1100	436900	183550
75	5	67	6540	5000	4650	4410	4080	2730	2100	1950	1830	1650	655350	275325
100	7	100	8730	6700	6200	5800	5450	3650	2800	2600	2450	2200	873800	367100
150	8	134	13080	10000	9300	8820	8160	5475	4200	3900	3675	3300	1310070	550650
200	10	200	16460	13400	12400	11600	10900	7300	5600	5200	4900	4400	1747600	734200
250	11	267	21810	16700	15500	14620	13610	9125	7000	6500	6125	5500	2184500	917750
300	12	333	25190	20100	18600	17400	16350	10950	8400	7800	7350	6600	2621400	1101300

(Courtesy of Williams Tool Co.)

PART SIXTEEN

Condensation of Gasoline from Natural Gas

GASOLINE GAS—LIQUEFIED GAS

The comparatively recent development of processes for utilizing "casing head gas" by extracting gasoline from it, is one of the greatest steps taken during the past ten or fifteen years toward true conservation of natural gas resources.

The extraction of gasoline from gasoline gas is practically a process of compression and refrigeration.

While laboratory tests may show that it is possible to obtain from six to twelve gallons of gasoline from 1000 cubic feet of gas, it is always safer to figure from three to six gallons per 1000 cubic feet.

There have been many instances where "casing head gas" has, after compression and refrigeration, proven not to have carried enough gasoline to make it a profitable proposition. This was due to the gas having come through an oil bearing strata, where the oil was of an asphaltum basis, and therefore very low in paraffin hydrocarbons for the gas to pick up.

Before constructing a very expensive refining or compressing plant, practical experiments with small plants should be carefully carried out and chemical analysis, while necessary, should not be depended upon entirely.

It is more profitable to manufacture the lower gravity gasoline (even though less of it is obtained from 1000 cubic feet of gas) than it is to install expensive machinery and extract a greater number of gallons of high gravity, because the latter is so volatile that one is able to market but a fraction of the quantity actually made.

All "casing head gas" contains hydrocarbons of the higher orders in the paraffin group, such as Propane, Butane,

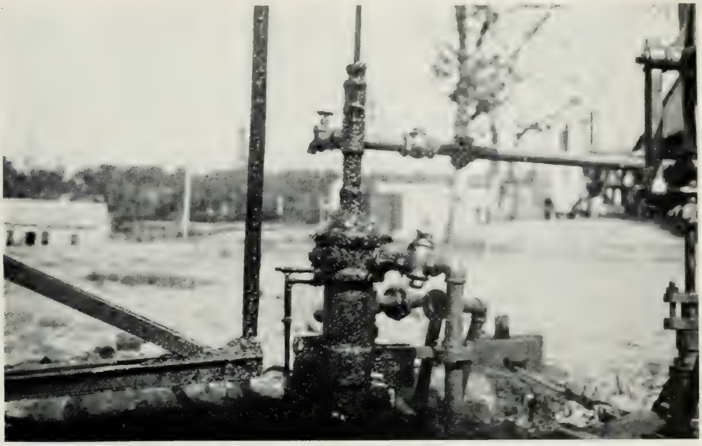


Fig. 220—A PUMPING OIL WELL SHOWING "CASING HEAD" AND LEAD LINES TO CARRY THE GASOLINE GAS TO THE COMPRESSING PLANT

Pentane and Hexane, and it is the relative percentage of these present in the gas that determines the quantity and quality of the gasoline that may be extracted from it.

The specific gravity of this "casing head gas" often runs as high as 1.50 (air = 1.0), due to the large percentage of heavy hydrocarbons present.

The heating value of casing head gas, in B. t. u. per cu. ft., is extremely high, due to the presence of the rich hydrocarbons above mentioned. When these are extracted in the form of so-called gasoline, the gas remaining has the heating value and other properties of normal "dry" natural gas, being, in fact, in the condition in which it existed before it picked up the higher hydrocarbon vapors in its passage through the oil bearing sands.

The volume ratio of dry residue gas to the wet gas before the gasoline is extracted varies from 0.60 to 1.00, depending upon the quantity and quality of gasoline extracted. That is, from 600 to 1000 cubic feet of dry gas will remain after extracting the gasoline from 1000 cubic feet of wet gas.

High gravity gasoline lies dormant when cold, but as its temperature rises above its boiling point it begins to agitate or boil, creating a vapor tension in the tank or drum which raises the boiling point to that corresponding to the increased vapor pressure, thus maintaining a condition of equilibrium.

The gravity of gasoline may be reduced by mixing with it a quantity of lower gravity gasoline. For instance, 50 lb. of 86 deg. gravity gasoline mixed with 50 lb. of 56 deg. gravity gasoline will give 100 lb. of 71 deg. gravity gasoline. This does not, however, result in a stable mixture if left unconfined, as the lighter gravity gasoline will gradually evaporate from the mixture.

Gasoline Gas Industry (*By O. J. Sieplein, Ph. D.*)—"All liquids, when exposed to the air or to any gas, gradually change to vapor. The rate at which this change takes place increases as the temperature of the liquid rises. When the vapor is being formed quietly, we speak of the liquid as evaporating or vaporizing. When the temperature is sufficiently high, the vapor forms rapidly in the body of the liquid and appears as bubbles which rise through the liquid. We say the liquid is boiling, and its temperature is its boiling point. If the liquid is pure, the boiling point will remain constant as long as there is any liquid. If we are dealing with a mixture of two liquids of different boiling points the boiling will usually begin at the boiling point of the lower boiling liquid. The temperature will gradually rise as the boiling continues, until, as the last portion boils away, the temperature has reached the boiling point of the higher boiling liquid. By boiling the liquid slowly, condensing the vapors and collecting the first portions of condensate separately from the later ones, we bring about a rough separation of the two constituents of the mixture. This is the principle made use of in the separation of petroleum into its various products by distillation, also in the manufacture of the various distilled liquors.

Fig. 221 RENO GASOLINE PLANT AT SISTERSVILLE, WEST VIRGINIA
One of the First Installed.

The boiling point of liquid varies with the pressure exerted upon the liquid. Thus, water can be made to boil at any temperature from 32 deg. fahr. to 698 deg. fahr. Inasmuch as the normal pressure of the air is fifteen pounds per square inch, and the boiling point of water at this pressure is 212 deg. fahr., we ordinarily speak of 212 deg. fahr. as the boiling point of water.

If we close a vessel partly full of water, with a safety valve set at fifteen pounds, the pressure of the steam, i. e., the pressure on the water, when boiling takes place and the valve is opened, is fifteen pounds greater than the pressure of the air, or a total of thirty pounds. The boiling point at this pressure is 249 deg. fahr. Similarly the boiling point for a valve pressure of thirty pounds (a total pressure of 45 pounds) is 273 deg. fahr. Speaking of these facts from a mechanical engineer's standpoint, we would say the temperature of saturated steam at fifteen pounds is 249 deg. fahr. and at thirty pounds is 273 deg. fahr.

Previous to 1880, it was thought impossible to liquefy certain gases such as air and hydrogen. These were therefore known as permanent or perfect gases. Following up the work of Cailletet, Pictet, Dewar and others in the perfection of means of producing and maintaining cold, all gases have been liquefied. The last to be liquefied was helium, an inert gas first discovered in the sun and later found to be present in the air and some minerals. The boiling point of hellium is the lowest known, it being 451.6 deg. fahr. below zero. The invention by Dewar of vacuum-jacketed vessels aided more than any other one thing in the development of our knowledge in the field. This invention has become of commercial importance, its outgrowth being the vacuum-jacketed bottle such as the thermos.

It was early recognized that there is a certain definite temperature for each substance above which it cannot be liquefied by pressure. This temperature is known as the critical temperature, and the pressure needed to produce the liquid at this temperature as the critical pressure. An example will make this point clear.

The critical temperature of water is 698 deg. fahr.; its critical pressure is 2.933 pounds per square inch. This means that at a temperature below 698 deg. fahr. steam may, by application of pressure, be converted to liquid

water, and that at 698 deg. fahr. 2.933 pounds are necessary. Stated otherwise, it means that steam generated at this temperature has a total pressure of 2.933 pounds or a noticeable pressure of 2.918 pounds, the excess above the atmospheric pressure of 15 pounds. At the critical temperature the liquid passes over into the gas without expansion.

The term vapor is now applied to gases below their critical temperatures—that is, to gases which by pressure alone can be converted to liquids. The term, true, perfect, or permanent gas, is applied to gases above their critical temperatures.

The volume of a gas is increased by the application of heat. These facts are known to anyone who is observant. Scientific experiment has proven that these changes in volume are perfectly regular for true gases, and are independent of the nature or composition of the gas. The changes in volume for a given change in temperature or pressure are the same for all true gases. Double pressure reduces the volume of a gas to one-half the original volume; triple pressure reduces it to one-third, etc. Four hundred and sixty cubic feet of gas at 0 deg. fahr. will increase one cubic foot for each degree that the temperature is raised. It would be 470 cubic feet at 10 deg. fahr., 480 cubic feet at 20 deg. fahr., etc. An increase of pressure on a gas meets with a certain resistance, which resistance is expressed as heat, warming the gas. If the change in pressure is gradual, the heat is radiated to surrounding objects, and not noticed. If, as in commercial practice, the change in pressure is sudden, the heat does not have opportunity to radiate and the warming of the gas is considerable. Therefore the volume resulting on doubling the pressure would be more than one-half the original volume because the temperature of the compressed gas is higher than that of the original gas. This increase of temperature varies with original temperatures, original pressures, final pressures, and also with the amount

of radiation. The loss of heat by radiation is dependent on the nature of the containing vessel.

Whenever a gas bubbles through or comes into contact with a liquid it takes up vapor of that liquid. The amount of vapor, as would be inferred from former statements, increases as the temperature rises and is quite independent of the nature of the gas. Inasmuch as in the resulting mixture the gas is mixed with vapor the mixture occupies more space than the original gas. Thus 1,000 cubic feet of dry air at 50 deg. fahr. will take up nine and one-third ounces by weight of water yielding 1,012 cubic feet of moist air; 1,000 cubic feet of dry air at 80 deg. fahr. will take up twenty-five ounces, by weight, of water, yielding 1,035 cubic feet of moist air.

When natural gas in the earth comes into contact with petroleum it takes up some of the petroleum as vapor. Petroleum is composed of a large number of substances, with boiling points ranging from 320 deg. fahr. to perhaps 1,000 deg. fahr. The low boiling constituents of petroleum, when separated from the others by distillation, compose the various grades of gasolines. Higher boiling portions constitute the various grades of burning oils, paraffin, etc. Inasmuch as the temperature of the gas in the earth is nearer the boiling points of the gasoline constituents of the petroleum, these are taken up in much larger amounts than any other portions.

If the well is under vacuum the boiling points of the various portions are lowered. Thus the temperature of the natural gas is still nearer the boiling points of the gasoline portions and greater evaporation takes place. On the other hand, if the gas is present in the well under high pressure, this pressure on the petroleum raises the boiling points. The temperature of the gas is far from the boiling points of even the gasoline constituents and consequently vaporization is small. This is exactly what we find in practice. From

petroleum and gas of the same character, the gas from a well under vacuum is richer in gasoline vapor than that from a well under pressure.

When we have a mixture of gases exerting a certain total pressure, each individual constituent of the mixture exerts that fraction of the total pressure. For example, air is roughly one-fifth oxygen and four-fifths nitrogen. Of the ordinary atmospheric pressure of fifteen pounds, oxygen is exerting one-fifth or three pounds while the nitrogen is exerting four-fifths or twelve pounds. If we fill a cylinder or any other vessel with air, we would find exactly the same ratio of oxygen to nitrogen in all parts of the vessel. That is, the oxygen and nitrogen are each present in all parts of the vessel. Each cubic inch of the vessel would contain 0.07 grains of oxygen and 0.25 grains of nitrogen. This corresponds to one-fifth of a cubic inch of oxygen and four-fifths of a cubic inch of nitrogen, if both gases are under a pressure of fifteen pounds. From five cubic feet of air we could therefore obtain one cubic foot of oxygen and four cubic feet of nitrogen, if all these were under fifteen pounds pressure. From the law of gas volume in relation to pressure, if we transfer the one cubic foot of oxygen at fifteen pounds to a five-cubic-foot cylinder, the pressure in this cylinder would be three pounds. This is one-fifth of fifteen pounds. Similarly the four cubic feet of nitrogen would exert twelve pounds pressure if transferred to a five-cubic-foot cylinder. Now suppose the five cubic feet of oxygen at three pounds to be added to the five cubic feet of nitrogen at twelve pounds. Suppose also that the space occupied by the mixture be restricted to five cubic feet. The pressure must necessarily be the sum of three pounds and twelve pounds, or fifteen pounds.

In order to condense vapor, pressure must be exerted upon it or it must be cooled. If we wish to condense it by pressure alone, we must exert a pressure equal to the pressure of the vapor when the liquid is boiling at the temperature of

the experiment. But if the vapor is present in mixture with another gaseous substance, only a portion of the total pressure is being exerted on the vapor. If the vapor constitutes ten per cent. of the mixture, the pressure on the vapor is ten per cent. of the pressure on the mixture. In such a case we would need 150 pounds pressure on the mixture to have fifteen pounds on the vapor. With the pressure of fifteen pounds on the vapor, this would condense to a liquid at the temperature at which the liquid would normally boil.

Commercial cymogene is mainly butane which boils at 34 deg. fahr. That is, at 34 deg. fahr. butane vapor exerts a pressure of fifteen pounds. To condense butane vapor at 34 deg. fahr. to a liquid by the application of pressure, we would need fifteen pounds per square inch. If the butane constituted twenty per cent. of a mixture, we would need a total pressure of seventy-five pounds in order to have fifteen pounds on the butane vapor. If the butane were ten per cent. of the mixture, a total pressure of 150 pounds would be necessary. With five per cent. of butane, a pressure of 300 pounds would be needed. From this it will be seen why one gas may produce gasoline with 75 to 100 pounds, while another gas will need 250 to 300 pounds to produce the same quality of gasoline.

Butane is either liquid or gas as temperature and pressure conditions may demand. As a gas it weighs almost exactly twice as much as the same volume of air. As a liquid, it weighs almost exactly (a little over) five pounds per gallon. Air weighs at sea level pressure and zero fahr. temperature 86 pounds per thousand cubic feet. A thousand feet of butane would produce about thirty-four gallons of gasoline. Then when the specific gravity of a gas runs up in the neighborhood of one-and-a-half as referred to air, we may easily suspect that more than three-and-one-half gallons of condensate can be recovered from it.''

PRODUCTION OF GASOLINE FROM NATURAL GAS IN THE UNITED STATES IN 1912 AND 1913, BY STATES *

1912

State	Number of operators	Plants: Number in operation	Plants: Daily capacity	Gasoline produced: Quantity	Gasoline produced: Value	Gasoline produced: Price per gallon.	Gas used: Estimated quantity.	Gas used: Value	Average yield in gasoline.
			Gallons	Gallons		Cents	Cubic feet		Gallons
West Virginia	66	97	22,366	5,318,136	$513,116	9.6	1,972,882,212	$163,749	2.8
Pennsylvania	69	83	10,524	2,041,109	217,016	10.6	722,730,117	62,010	2.8
Ohio	25	43	7,791	1,718,719	173,421	10.1	675,123,700	46,090	2.98
Oklahoma	11	13	11,910	1,575,644	99,626	6.3	701,044,300	24,901	2.25
California	7	7	6,669	1,040,695	112,502	10.8	600,743,000	25,573	1.7
Illinois	4	4							
Colorado	2	2	2,008	386,876	41,795	10.8	114,273,000	9,662	3.4
New York	1	1							
Kentucky	1	(a)							
Total	186	250	61,268	12,081,179	1,157,476	9.6	4,687,796,329	331,985	2.6

a Drips *Hill, B.—Production of Natural Gas in 1913.

1913

State	Number of operators	Plants		Gasoline produced			Gas used		Average yield in gasoline
		Number in operation	Daily capacity	Quantity	Value	Price per gallon	Estimated quantity	Value	
			Gallons	*Gallons*		*Cents*	*Cubic Feet*		*Gallons*
West Virginia	63	115	31,930	7,662,493	$807,406	10.54	2,981,119,000	$181,337	2.57
Oklahoma	19	40	61,633	6,462,968	577,944	8.94	2,512,503,000	82,742	3.00
Pennsylvania	100	113	22,207	3,680,096	405,186	11.01	1,372,056,000	114,783	2.68
California	12	14	21,135	3,460,747	376,227	10.87	2,436,445,000	106,539	1.42
Ohio	25	41	8,142	2,072,687	212,404	10.25	744,226,000	63,233	2.79
Illinois	6	12							
Colorado	2	2							
New York	3	3	7,368	721,826	79,276	10.98	203,092,500	17,590	3.55
Kansas	1	1							
Kentucky	1	(*a*)							
Total	232	341	152,415	24,060,817	2,458,443	10.22	9,889,441,500	566,224	2.43

a Drips. *Hill, B.—Production of Natural Gas in 1913.

According to these figures the increase in the production of gasoline from natural gas in the United States for the year 1913 over the year 1912 was about 100 per cent. According to the United States Geological Survey figures, the rate of increase for 1912 over 1911 was 63 per cent.

ANALYSES OF NATURAL GAS FOR GASOLINE CONTENT *

Analysis No.	Date of analysis	Location of field	Absorption heavy hydrocarbons	Carbon dioxide	Oxygen	Nitrogen	Specific gravity	Combustion ratios			R.	R[1].	Gallons per thousand cubic feet of gas
								Contraction	CO_2	O_2			
			Per ct.										
2500	Apr. 2, 1913	Calgary, Alberta, Can.	15	None	None	None	0.67	2.17	1.26	2.37	1.72	0.390	Dry
2430	Jan. 25, 1913	Electra, Tex.	50	None	None	None	1.12	2.56	2.03	3.59	1.26	.889	3.5
2242	May 20, 1912	Oilfields, Cal.	36	17.0	0.70	3.8	.79	2.21	1.13	2.34	1.96	.403	1.0
2747	Nov. 17, 1913	Casper, Wyo.	45.1	None	None	None	1.04	2.57	1.98	4.54	1.29	.806	3.0
2748	do	do	35.5	None	None	None	.94	2.47	1.72	3.19	1.44	.653	2.0
1477	Feb. 23, 1911	Glen Pool, Okla.	62.5	4.7	.80	3.0	1.16	2.62	2.15	3.77	1.22	.951	4.
2181	Jan. 2, 1912	Childers, Okla.	79.3	None	None	None	1.37	2.89	2.55	4.43	1.13	.120	5.5
2065	July 17, 1911	Bremen, Ohio.	25.0	None	.30	(*a*)	.67	2.09	1.10	2.19	1.98	.338	Dry
D45	Oct. 17, 1911	Cherryvale, Kans.	21.2	.95	None	None	.60	2.03	1.01	2.04	2.00	.300	Dry
2533	Apr. 28, 1913	Titusville, Pa.	49.2	1.50	None	None	.90	2.48	1.64	3.13	1.51	.596	2.
1632	Mar. 18, 1911	Sistersville, W. Va.	45	.70	6.90	28.3	1.52	2.82	2.89	4.72	.976	1.56	Air-free
1186	Jan. 26, 1910	do	62.0	None	2.5	(*a*)	1.23	2.72	2.24	3.95	1.21	1.02	4.5
1494	Feb. 23, 1911	Kiefer, Okla.	68.6	3.90	None	None	1.30	2.66	2.19	3.85	1.21	1.07	5.
2478	Mar. 1, 1913	Charleston, W. Va.	22	None	None	None	.74	2.24	1.29	2.54	1.73	.427	.5
A-1-5	Feb. 10, 1910	Grove City, Pa.	15	None	None	None	.63	2.04	1.02	2.06	2.00	.315	Dry

*Hill, B.—The Production of Natural Gas in 1913. *a* Not determined.

EXPERIMENTS IN LIQUEFYING CRUDE NATURAL GAS

Properties of crude natural gas and of the volatilized liquid products of compression
(G. A. Burrell, *Analyst*)

Analysis No.	Kind of Gas	Specific gravity[a] (air=1).	Heating value per Cu. Ft. (0°C. and 760 mm. pressure)	Composition: Methane	Composition: Ethane	Composition: Propane	Composition: Butane	Composition: Nitrogen
			B. t. u.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	Natural gas (Pa. and W. Va.)	0.64	1,189	83.0	16.4	....	....	0.6
2	Natural gas (Follansbee, W. Va.)	1.39	2,468	....	21.8	77.7	....	0.5
3	Residual gas after 50-pound compression product has been removed	1.35	2,364	....	34.9	64.6	....	0.5
4	Residual gas after 250-pound compression product has been removed	1.15	2,008	....	79.4	20.0	....	0.6
5	Gas from liquefied gas (400 pounds pressure, 0° C.).	1.01	1,808	3.8	95.0	....	....	1.2
6		....	2,066	....	72.5	27.0	....	0.5
7		1.28	2,214	....	52.1	46.9	....	1.0
8		....	2,621	....	1.1	98.0	....	0.9
9	....do.	1.02	1,816	4.7	94.9	....	....	0.4
10		....	1,925	....	89.3	9.9	....	0.8
11		....	2,108	....	67.0	32.5	....	0.5
12		....	2,161	....	59.4	39.8	....	0.8
13		....	2,708	....	....	89.2	9.9	0.9
14		....	3,221	....	....	24.0	75.0	1.0

[a] By effusion method.
From Technical Paper No. 10—Bureau of Mines. *By Irving C. Allen and George A. Burrell.*—1912.

B. t. u. at 60 deg. fahr.	NAME	Chemical Symbol	Boiling Point deg. fahr.
1003	Methane	CH_4	−256.5
1754	Ethane	C_2H_6	−135.4
2496	Propane	C_3H_8	−49.0
3241	Butane	C_4H_{10}	+33.8
3995	Pentane	C_5H_{12}	+100.4
4712	Hexane	C_6H_{14}	+158.0
	Heptane	C_7H_{16}	+208.4
	Octane	C_8H_{18}	+257.0
	Nonane	C_9H_{20}	+298.3
	Decane	$C_{10}H_{22}$	+334.3
	Dodecane	$C_{12}H_{26}$	+395.7
	Hexadecane	$C_{16}H_{34}$	+532.3

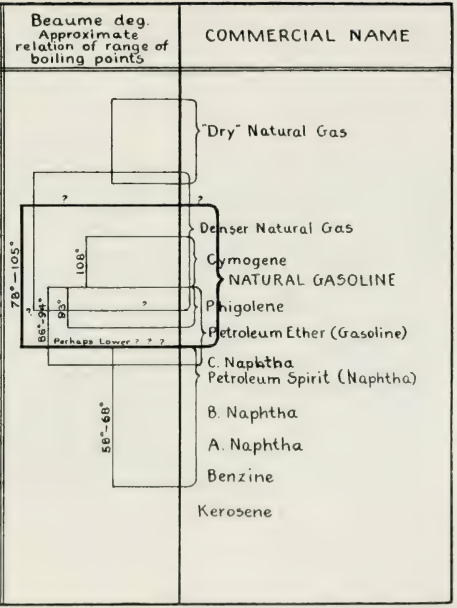


Fig. 222—TABLE SHOWING DIFFERENT HYDROCARBONS FOUND IN LIGHT AND HEAVY GASES

Analysis of Natural Gas for Gasoline Content. (By R. A. Bastress, Chemist)—"One of the initial steps taken to distinguish a "wet" gas from a "dry" gas was to find a suitable solvent in which the heavier hydro-carbons of a "wet" gas were soluble and in which the lighter hydro-carbons of a "dry" gas were insoluble. Various solvents were tried with more or less success. After many experiments it was found to be expedient to use claroline oil, due to its uniformity and stability. Other solvents tried were alcohol, kerosene, olive oil and lubricating oils.

Claroline oil is a mineral oil bought under the trade name of glycerine vitae. It has the following characteristics: (*a*)

> Specific gravity equals .8667 at 15° C.
> Viscosity equals 4.4° Engler at 20° C.
> Flash point equals 152° C. Pensky-Martens closed test.
> Ignition point equals 270° C. Pensky-Martens closed test.

(*a*) The solubility of pure methane in claroline oil was found to be 11.0 per cent.

The absorption of gasoline producing gases has been found to range from 25 to 92 per cent. Pure gasoline vapor was found to be completely soluble.

A cut of a field analysis case is shown. It is identical with the one used in laboratory for absorption of hydro-carbons, except that it is shown in portable case.

The following procedure is carried on in the absorption analysis:

One of the burettes is filled with water and is a measuring tube. A sample of gas to be tested is taken into this tube (about 80 c. c.) and the exact volume noted; it is then forced into the other burette containing claroline oil, by raising and lowering respective leveling bottles. This burette is the

(*a*) From Government Publication, Bulletin 88, page 34.

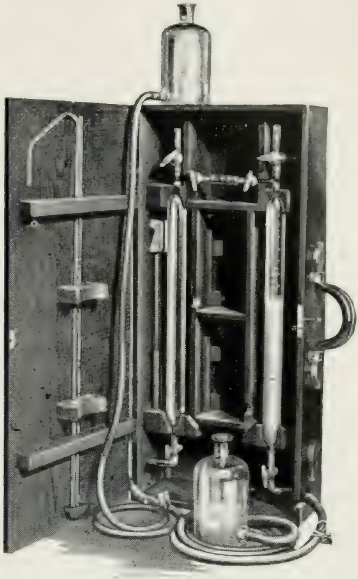


Fig. 223—FIELD APPARATUS FOR ANALYZING GASOLINE GAS

absorption tube. It is now placed in cold water and agitated at regular intervals. The leveling bottles are placed in a position higher than the tube, and contain a surplus of oil, which replaces the gas as it is absorbed. After thirty minutes the gas is run back into measuring tube and decrease in volume noted and taken as absorption. As a precaution the gas should be again placed in the oil absorption tube and further agitated and cooled and again measured, observing whether any further absorption takes place. The two consecutive readings should check. If not, further absorption should be permitted. Experiments have shown that by agitating at three minute intervals for thirty minutes, complete absorption is effected. It is important that the same

conditions exist to get check results, that is, temperature, size of sample and agitation.

Example:

80.5 c c	equals	Sample of gas
40.2 c c	"	Residue gas
40.3 c c	"	Absorbed

$\frac{40.3}{80.5}$ x 100 equals 50.00% absorption.

By use of modified Orsat's apparatus, impurities such as CO_2, air and N_2 are determined, and combustion analysis made.

CO_2 is determined by absorption in Potassium hydroxide contained in one of the glass bulbs the same as the oil absorption, excepting that cooling or agitation is not necessary and complete absorption takes place in five minutes.

O_2 is determined in the same manner, except that alkaline pyrogallate is the solvent used.

By means of combustion of gas with pure O_2, from which contraction and CO_2 are obtained, we are able to make comparison with contraction and CO_2 of pure hydrocarbons, methane, ethane, etc. From this combustion data we are also able to calculate empirical formula of the gas, as Cx Hy.

Nitrogen is determined by the difference after exploding a mixture of gas and pure O_2 and absorbing the products of combustion and excess O_2.

Along with given analysis the gravity is determined by the effusion method in a Schilling's specific gravity apparatus. See page 85.

Following are some analyses of gases from different fields with gasoline content estimated:

Analysis No.	Location or field	Absorption by oil, %	CO_2 %	Air %	Empirical formula from comb.data	Sp.Gr. Air as 1	Yield in gals.	Remarks
A-1-5	Grove City, Pa.	15.0	None	None	$C_{1.02}H_{4.16}$	.63	None	
B-64	Beaver Co., Pa.	61.1	1.55	None	$C_{2.46}H_{6.80}$	1.40	5.0	This has been proven commercially.
B-59	Hollidays Cove, W. Va.	87.0	.15	None	$C_{2.79}H_{8.36}$	1.42	5.0	Commercial operation shows 5-6 gals.
2747	Casper, Wyo.	45.1	None	None	$C_{1.98}H_{6.28}$	1.04	3.0	Physical test plant showed 3.13 gals. on this gas.
895	Bremen, O.	22.0	None	.70	$C_{1.01}H_{4.04}$	.65	None	By physical test this showed less than ½ gal. at 400 lb.
865	Steubenville, O.	80.0	None	7.25	$C_{2.47}H_{8.08}$	1.33	5.0	Plant shows even higher yield
892	Rock City, N. Y	64.0	None	None	$C_{2.10}H_{7.00}$	1.08	3.0	
867	Lincoln, Neb.	18.0	None	None	$C_{1.18}H_{5.20}$	.68	None	
846	Muskogee, Okla	23.0	.15	1.25	$C_{1.38}H_{5.36}$	.73	.5	This would not be a profitable yield.
1477	Glen Pool, Okla	62.5	4.70	4.00	$C_{2.15}H_{6.48}$	1.16	4.0	Successful plant operating on this gas.
1494	Kiefer, Okla	68.6	3.90	None	$C_{2.19}H_{6.64}$	1.30	4.5	Successful plant operating on this gas.
2137	Sapulpa, Okla	38.0	5.10	None	$C_{1.18}H_{4.52}$	.76	.75	
2679	Robinson, Ill.	24.0	5.50	1.00	$C_{1.28}H_{4.92}$	.74	.50	
2560	Shreveport, La	42.0	.60	1.10	$C_{1.95}H_{6.36}$	.96	2.50	
2540	Mt. Jewett, Pa	67.0	None	2.50	$C_{1.98}H_{6.64}$	1.03	3.00	A profitable plant operates on this gas.
2085	Bakersfield, Cal	39.0	10.7	3.50	$C_{1.56}H_{5.76}$	.89	1.50	
2310	Tidioute, Pa.	46.0	None	None	$C_{1.79}H_{5.80}$	.94	2.00	
2327	Monticello, Ky.	39.0	None	1.50	$C_{1.52}H_{4.98}$	.91	1.50	
2295	Electra, Texas	57.0	None	3.5	$C_{2.14}H_{6.60}$	1.00	2.50	
2251	Tampico, Mexico	62.0	17.5	3.0	$C_{1.85}H_{6.08}$	1.08	3.00	
2259	Chanute, Kans	23.0	None	None	$C_{1.08}H_{4.40}$	.65	None	
2155	Sistersville, W. Va	78.5	None	6.5	$C_{2.30}H_{7.56}$	1.23	4.00	Plant is making even more than estimate.
2025	Cooper Tract, Pa.	67.0	None	None	$C_{1.87}H_{6.00}$	1.02	3.00	Successful plant verifies this estimate.

Note Estimates are based with supposition that gas is air-free.

It will be noted that the analysis scheme is a comparative one, using as standards, gases in which the gasoline content has been determined by actual operation, the success of which rests in the amount of experience the analyst has had to familiarize him with important characteristics of gases.

To make an analysis which would show the exact amount of gasoline vapor contained in a gas would require a separation and determination of each hydro-carbon. This would be possible by fractionating at very low temperatures, but would be a very long and expensive operation, making it impractical in a commercial laboratory, where speed and expense must be considered."

Use of Alcohol as a Solvent—The Bureau of Mines has used ethyl alcohol in much the same manner that claroline oil is used for testing natural gas. Instead of 35 c. c. of the claroline oil, 50 c. c. of ethyl alcohol may be used. The proceedure otherwise is exactly the same. The results obtained with alcohol are similar to those with claroline oil.

Orsat Apparatus for Determination of Carbon Dioxide and Oxygen (Bureau of Mines—Bulletin No. 88)—In figure 224 is shown an Orsat apparatus for the determination of carbon dioxide and oxygen in natural gas. The Orsat apparatus is so well known that it needs little description. It is sufficient to say that the burette has a capacity of 100 c. c. The pipette *b* contains caustic potash solution for the removal of carbon dioxide, and the pipette *a* contains alkaline pyrogallate solution for the removal of oxygen. The figure (Fig. 224) shows the level bottle of the burette, the water jacket, and a three-way stopcock, *c*. This apparatus may be used to advantage for examining natural gases to determine whether air has leaked into mains, owing to the reduced pressures that are maintained in pipe lines at some gasoline plants."

PROPERTIES OF SEVEN PARAFFIN HYDROCARBONS (Bureau of Mines—Paper No. 88)

Hydrocarbon	Formula	Boiling point *b*	Specific gravity (at 0°C. and 760 mm.; air=1)	Weight of 1 litre	Heating value per cubic foot at 0° C. and 760 mm. *c*	Illuminating value	Liquefaction point	Calculated volume of gas (at 60° F. and 30 inches pressure from 1 gallon	Theoretical volume of air necessary to burn 1 cubic ft. of gas
		°C.		*Grams*	*B. t. u.*	*British candle-power*	°C. *Lbs. per sq. inch*		*Cu. ft.*
Methane *d*	CH_4	—160	0.554	0.7159	1,065	5.0	—95.5 at 735 *f* —81.8 at 807 *g*	....	9.57
Ethane *d*	C_2H_6	—93	1.049	1.3567	1,861	*h* 35.0	+35 at 664 *i*	53	16.72
Propane *d*	C_3H_8	—45	1.520	1.9660	2,654	*h* 53.9	+97 at 647 *g*	45	23.92
Butane *d*	C_4H_{10}	1.0	2.004	2.594	3,447	....	....	37	31.10
Pentane *k*	C_5H_{12}	36.4	....	....	4,250	....	....	31	38.28
Hexane *k*	C_6H_{14}	68.9	....	....	5,012	....	....	27	
Heptane *k*	C_7H_{16}	98.4	....	....	....	....	....	....	

a A technical paper covering in detail this method of separating gases and the results of experiments by the bureau is being prepared.

b Holleman, A. F., Organic chemistry, edited by A. J. Walker, 1910, p. 41.

c Landolt and Bornstein, Physikalisch-chemische Tabellen, 3d ed., 1905, pp. 416, 425 (J. Thomsen).

d Gas at ordinary temperature.

e Wright, L. T., Illuminating power of methane; Jour. Chem. Soc., vol. 47, 1885, p. 200.

f Landolt and Bornstein, Physikalisch-chemische Tabellen, 3d ed., 1905, pp. 185 (Dewar).

g Landolt and Bornstein, Physikalisch-chemische Tabellen, 3d ed., 1905, p. 185 (Olszewski).

h Frankland, P., Illuminting power of methane; Jour. Chem. Soc., vol. 47, 1885, p. 235.

i Landolt and Bornstein, Physikalisch-chemische Tabellen, 3d ed., 1905, p. 182 (Dewar).

k Liquid at ordinary temperature.

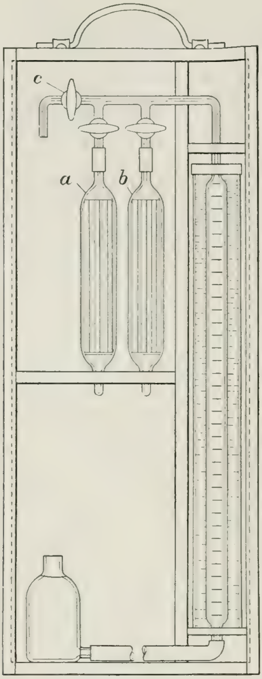


Fig. 224—ORSAT APPARATUS FOR DETERMINING CARBON DIOXIDE AND OXYGEN IN NATURAL GAS

Specific Gravity Outfit—The specific gravity outfit is a particular advantage to the operator in determining whether the gas from any one lease or well is of proper density to carry a sufficient amount of hydrocarbons to warrant having an analysis or test made.

By making a gravity test the density of the gas can be accurately determined. If in testing the gravity of a certain gas it is found to be near .6 which is the gravity of natural gas—to proceed further and have an analysis made would be useless. However, if the gravity proved to be .80 or greater (air=1) there would be little doubt of the gas carrying

enough hydrocarbons to make it profitable to compress and refrigerate.

If the gas proved to have a gravity of .80 or better than .80 it would be advisable to send a sample of the gas to some well known chemist or laboratory for analysis or better still to install a small portable compressor and cooling system to make a practical test to determine the actual amount and gravity of the gasoline extracted.

Because the gas is heavy it does not necessarily follow that it will yield gasoline in paying quantities.

Full instructions for using specific gravity outfit is given on page 85.

Interpretation of Results of Tests (from Bulletin No. 88 Bureau of Mines)—"Many experiments have shown that gasoline may be obtained from natural gas having a specific gravity of 0.80 and higher (air = 1). Some inconsistencies have been noted, however, so that the authors would hesitate to recommend the installation of a plant to handle a gas that tests showed to have a specific gravity as low as 0.80 or to have an absorption percentage of 30.0 (Bureau of Mines test), although the gas might be all right for the purpose, especially if it were from wells in a field where other gases of low specific gravity were already producing gasoline. The authors do believe, however, that a gas with a tested specific gravity as high as 0.95 and an absorption percentage as high as 40 might warrant an installation.

Natural gases differ much in composition. A so-called 'wet' gas might, for instance, contain a very large proportion of methane, with little ethane, propane, or butane, but enough of the gasoline hydrocarbons to warrant a plant installation. Such a gas when subjected to comparatively low pressures would deposit the gasoline vapors. Another gas of the same specific gravity might contain a comparatively small proportion of methane and ethane and a large proportion of propane and butane, but not enough of the

gasoline hydrocarbons to warrant plant installations. Therein lies the reason why specific gravity, solubility, or combustion tests can not always be relied on.

As regards a natural gas of low specific gravity and low absorption percentage (known as a 'lean' gas), the safest recourse is to test by means of a portable outfit consisting of a gas meter, small gas engine, compressor, cooling coils, and receiver. Such an outfit can be hauled from place to place on a wagon. This method is in all cases to be recommended as having distinct advantages over laboratory tests. However, it is true that tests made with the portable outfit may be misleading unless in charge of a careful and experienced person.

The authors have also used a small stationary outfit consisting of a meter with a capacity of 15,000 cubic feet per 24 hours, a small compressor, driven by a steam engine, 100-foot cooling coils made of 1-inch pipe, immersed in a tank of water, and a storage tank 5 feet high made of a 6-inch piece of pipe. To the latter was attached a relief valve which could be set to operate at the desired pressure. A trap was installed between the compressor and the cooling coils to catch oil that was sometimes brought from the wells with the gas. A glass gauge was connected to the storage tank to indicate the volume of condensate produced.

In conducting tests of a gasoline plant the plant is first operated for an hour or two to insure that everything is working well. The meter and oil pressure gauges must be in good order. The cooling coils should dip enough to drain readily the gasoline into the storage tank. The efficiency of the cooling coils can be ascertained fairly well by measuring the temperature at different places in the water of the tank. At the point where the coil enters the water it will be hot enough to warm the water appreciably, but if the tank is large and a sufficient length of pipe for cooling purposes is installed the warming of water is only local.

Compression and Liquefication of the Constituents of Natural Gas in Plant Operation—The condensation of gasoline from natural gas is essentially a physical process. If any chemical reactions take place, they are slight and inappreciable. The authors tested residual gases from 10 different plant operations to determine whether carbon monoxide or olefin hydrocarbons were produced. These gases with others are found when the higher paraffins are decomposed at high temperatures and pressures in the absence of air. Neither carbon monoxide nor olefin hydrocarbons were found.

Three Commercial Processes—At present three processes for the extraction of gasoline from natural gas are used commercially. The one most generally used involves compressing the gas to a certain pressure and subsequently cooling it by means of water or air. A second consists in simply cooling the gas without compression by means of a refrigerant, such as liquid ammonia, evaporating under reduced pressure. A third is a combination of the other two.

RESULTS OF TESTS OF THE GRADE AND QUANTITY OF GASOLINE PRODUCED WHEN CRUDE NATURAL GAS IS SUBJECTED TO DIFFERENT PRESSURES

Pressure	Temperature of cooling water	Gravity of gasoline	Yield of gasoline per 1,000 cubic feet of gas
Pounds per square inch	°*C.*	°*B.*	*Gallons*
110	10	.....	1.8
140	10	90	3.0
190	10	94	4.5

It has been found by experiment at this plant that pressures of 140 to 150 pounds per square inch produced the most marketable gasoline. It will be observed that a pressure of 190 pounds produced more gasoline. The extra 1½

gallons, however, was of such a volatile character that it only escaped into the atmosphere upon exposure to the air; hence high pressures at this plant were unnecessary. Gasoline could be obtained by the application of pressures as little as 50 pounds per square inch, but the yield was small.

As natural gas is of different character in many different sections of the country and even in the same oil field, data obtained at one plant can not always be used as a basis for operating other plants—that is, as far as the pressures that should be used are concerned. Each operator should thoroughly test his own gas. Different pressures should be applied and the quantity and character of the gasoline, noted. A reliable meter for measuring the gas becomes indispensable. If, in certain plants operating to-day, meters were installed and a series of tests conducted as above outlined much greater efficiency of operation could be attained. Other apparatus that could be used to advantage are thermometers, graduated vessels for measuring the gasoline, hydrometers for determining the specific gravity of the gasoline, and gas-analysis apparatus, especially an apparatus for detecting air leaks in pipes through analyses of the gas for oxygen."

Air in Casing Head Gas—Incidents have been known to the writer where the analysis of casing head gas from oil leases showed as much as 55% air while being pumped under minus or "vacuum" pressure. This was due to leaky casing heads or faulty fittings. It is good practice to have the pipe line system on each lease or group of leases so arranged that it is possible to put a pressure test on same and determine the leakage. Invariably a pressure test will show a number of small leaks and not any single leaks of large size. All leaks should be stopped.

The only true method of determining the amount of air in casing head gas from any one lease or group of leases is by analyzing the gas for oxygen with what is known as the Orsat Analyzing Apparatus fully described on page 538.

Orifice Well Tester This instrument is simple in construction, consisting of a short two inch nipple with pipe thread on one end, and a thin plate disc on the other. The disc carries a one-inch orifice and a hose connection for taking the pressure. It is specially intended for testing small gas wells and "casing head" gas from oil wells. As a rule the flow of gas from an oil well is rather small and it is not advisable to test the flow of the well with a pitot tube such as is used in testing large gas wells. In using the orifice tester it is necessary to know the specific gravity of the gas in order to obtain the flow. The majority of gasoline companies possess the specific gravity apparatus.

To use the orifice well tester, before attaching to casing head, allow well to blow into atmosphere until the head is reduced and the gas reaches its normal flow. Then attach the orifice tester and read the pressure on a syphon gauge. By referring to the tables on pages 543-545, the flow of the well will be found opposite the gauge reading. Capacities for various gravities are given in different columns.

The orifice in the instrument should be kept dry and uninjured, otherwise it will not give an accurate reading on the gauge.

For wells making a volume of gas of less than 15,000 cubic feet per 24 hours, use one or two domestic meters. By this method it is not necessary to know the specific gravity to obtain the measurement of the flow.

Fig. 225—ORIFICE WELL TESTER

CAPACITIES, IN CUBIC FEET, PER 24 HOURS, OF A ONE-INCH THIN PLATE ORIFICE.

THICKNESS OF PLATE, 1/8-INCH

USED IN TESTING SMALL GAS WELLS AND "CASING HEAD" GAS FROM OIL WELLS.

Specific Gravities—.6 to 1.75.

Temperature—60° fahr. Atmospheric pressure—14.4.

Pressure in Inches Water.	.6	.65	.7	.75	.8	.85
1	26,440	25,440	24,500	23,660	22,920	22,220
2	37,510	36,040	34,750	33,600	32,520	31,530
3	46,440	44,640	43,000	41,540	40,240	39,020
4	52,630	50,590	48,740	47,060	45,600	44,200
5	57,880	55,630	53,610	51,790	50,160	48,640
6	63,140	60,720	58,480	56,490	54,720	53,060
7	68,110	65,470	63,090	60,910	59,040	57,210
8	73,050	70,220	67,680	65,350	63,310	61,390
9	77,680	74,680	72,000	69,500	67,340	65,280
10	82,340	79,150	76,270	73,650	71,370	69,190
11	86,680	83,320	80,300	77,540	75,120	72,840
12	90,720	87,190	84,000	81,140	78,600	76,220
Mercury.						
½	67,200	64,600	62,300	60,100	58,200	56,500
1	95,200	91,500	88,200	85,100	82,500	80,000
1½	116,600	112,000	108,000	104,300	101,000	97,900
2	134,600	129,400	124,700	120,400	116,700	113,100
2½	145,600	139,900	134,900	130,200	126,200	122,400
3	164,900	158,500	152,700	147,500	142,900	138,600
3½	178,200	171,300	165,100	159,400	154,500	149,800
4	190,400	183,000	176,400	170,300	165,000	160,000
5	212,900	204,600	197,200	190,400	184,500	178,900
6	233,200	224,100	216,000	208,600	202,100	195,900
7	251,900	242,100	233,400	225,300	218,300	211,700
8	269,400	258,900	249,500	240,900	233,400	226,400
9	285,700	274,600	264,700	255,600	247,600	240,100
10	301,200	289,500	279,000	269,400	261,000	253,100
11	315,800	303,600	292,500	282,500	273,700	265,400
12	328,400	315,700	304,200	293,800	284,600	276,000

CAPACITIES, IN CUBIC FEET, PER 24 HOURS, OF ONE-INCH THIN PLATE ORIFICE.

THICKNESS OF PLATE, ⅛-INCH

USED IN TESTING SMALL GAS WELLS AND "CASING HEAD" GAS FROM OIL WELLS.

Specific Gravities—.6 to 1.75.

Temperature—60° fahr. Atmospheric pressure—14.4.

Pressure in Inches Water.	.9	.95	1.	1.05	1.1	1.15
1	21,600	21,020	20,520	20,010	19,560	19,120
2	30,640	29,800	29,080	28,360	27,720	27,120
3	37,940	36,880	36,000	35,130	34,320	33,550
4	42,980	41,800	40,800	39,790	38,880	38.040
5	47,280	45,980	44,880	43,770	42,760	41,830
6	51,600	50,180	48,960	47,760	46,650	45,640
7	55,630	54,120	52,800	51,500	50,320	49,220
8	59,680	58,050	56,640	55,240	54,000	52,800
9	63,480	61,720	60,240	58,800	57,430	56,160
10	67,270	65,420	63,840	62,280	60,860	59,520
11	70,800	68,880	67,200	65,560	64,080	62,660
12	74,110	72,000	70,320	68,610	67,030	65,560
Mercury.						
½	54,900	53,400	52,100	50,800	49,600	48,600
1	77,800	75,600	73,800	72,000	70,300	68,800
1½	95,300	92,600	90,400	88,200	86,200	84,300
2	110,000	107,000	104,400	101,800	99,500	97,300
2½	118,900	115,700	112,900	110,100	107,600	105,300
3	134,700	131,000	127,800	124,700	121,800	119,200
3½	145,600	141,600	138,200	134,800	131,700	128,800
4	155,600	151,300	147,600	144,000	140,700	137,600
5	174,000	169,200	165,000	161,000	157,300	153,900
6	190,500	185,300	180,800	176,400	172,300	168,600
7	205,800	200,200	195,300	190,600	186,200	182,100
8	220,100	214,000	208,800	203,700	199,100	194,700
9	233,500	227,000	221,500	216,100	211,200	206,500
10	246,100	239,300	233,500	227,800	222,600	217,700
11	258,000	250,900	244,800	238,900	233,400	228,300
12	268,400	261,000	254,600	248,400	242,700	237,400

CAPACITIES, IN CUBIC FEET, PER 24 HOURS, OF A ONE-INCH THIN PLATE ORIFICE.

THICKNESS OF PLATE, 1/8-INCH

USED IN TESTING SMALL GAS WELLS AND "CASING HEAD" GAS FROM OIL WELLS:

Specific Gravities—.6 to 1.75.

Temperature—60° fahr. Atmospheric pressure—14.4.

Pressure in Inches Water.	1.2	1.3	1.4	1.5	1.6	1.7
1	18,720	18,000	17,320	16,750	16,200	15,720
2	26,540	25,480	24,570	23,760	22,990	22,290
3	32,850	31,560	30,400	29,370	28,440	27,600
4	37,220	35,760	34,460	33,310	32,230	31,270
5	40,940	39,360	37,920	36,620	35,470	34,410
6	44,680	42,960	41,370	39,960	38,680	37,530
7	48,190	46,320	44,610	43,100	41,730	40,480
8	51,690	49,680	47,850	46,220	44,760	43,410
9	54,960	52,800	50,880	49,170	47,610	46,200
10	58,240	55,960	53,920	52,100	50,440	48,960
11	61,320	58,920	56,780	54,860	53,110	51,520
12	64,170	61,680	59,400	57,400	55,580	53,920
Mercury.						
½	47,500	45,700	44,000	42,500	41,100	39,900
1	67,300	64,700	62,300	60,200	58,300	56,600
1½	82,500	79,200	76,300	73,800	71,400	69,300
2	95,300	91,500	88,200	85,200	82,500	80,000
2½	103,000	99,000	95,400	92,200	89,200	86,500
3	116,600	112,000	108,000	104,300	101,000	98,000
3½	126,100	121,200	116,700	112,800	109,200	105,900
4	134,700	129,400	124,700	120,500	116,600	113,200
5	150,600	144,700	139,400	134,700	130,400	126,500
6	165,000	158,500	152,700	147,600	142,900	138,600
7	178,200	171,200	165,000	159,400	154,300	149,700
8	190,600	183,100	176,400	170,500	165,000	160,100
9	202,100	194,200	187,100	180,800	175,000	169,800
10	213,100	204,700	197,300	190,600	184,500	179,000
11	223,400	214,700	206,800	199,900	193,500	187,700
12	232,400	223,300	215,100	207,900	201,200	195,200

Pipe Line Capacities for Gas at a "Vacuum" or Minus Pressure. Specific Gravity .6, for other Specific Gravities see table, page 560.

Capacity of 2″ Pipe Line, 1 Mile Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	50,000	38,000	....	....	....	....
5″—	66,000	58,000	43,000	....	....	....
Atmos. 0	81,000	75,000	65,000	48,000	....	....
Lb. per sq. in. 3	100,000	95,000	87,000	75,000	58,000	....
6	119,000	114,000	108,000	99,000	86,000	64,000
10	143,000	139,000	134,000	127,000	118,000	102,000

Capacity of 2″ Pipe Line, 2 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	35,000	27,000	....	....	....	....
5″—	47,000	41,000	31,000	....	....	....
Atmos. 0	58,000	53,000	46,000	34,000	....	....
Lb. per sq. in. 3	71,000	67,000	62,000	53,000	41,000	....
6	84,000	81,000	76,000	70,000	61,000	45,000
10	101,000	99,000	95,000	90,000	83,000	72,000

These Tables are based on gas of .6 specific gravity.
For other specific gravities, apply multiplier found in Table, page 563.

Capacity of 2″ Pipe Line, 3 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	29,000	22,000	....	....	....	....
5″—	38,000	33,000	25,000	....	....	....
Atmos. 0	47,000	43,000	37,000	28,000	....	....
Lb. per sq. in. 3	58,000	55,000	50,000	44,000	34,000	....
6	68,000	66,000	62,000	57,000	50,000	37,000
10	83,000	80,000	77,000	73,000	68,000	59,000

Capacity of 3″ Pipe Line, 1 Mile Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	138,000	106,000	....	....	....	....
5″—	183,000	161,000	121,000	....	....	....
Atmos. 0	227,000	209,000	180,000	134,000	....	....
Lb. per sq. in. 3	279,000	265,000	243,000	210,000	162,000	....
6	331,000	318,000	300,000	275,000	240,000	177,000
10	399,000	389,000	374,000	354,000	328,000	285,000

These Tables are based on gas of .6 specific gravity.
For other specific gravities, apply multiplier found in Table, page 563.

Capacity of 3″ Pipe Line, 2 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	98,000	75,000	....	....	....	....
5″—	130,000	114,000	85,000	....	....	....
Atmos. 0	161,000	148,000	127,000	95,000	....	....
Lb. per sq. in. 3	197,000	187,000	171,000	149,000	115,000	
6	234,000	225,000	212,000	194,000	170,000	125,000
10	282,000	275,000	264,000	250,000	232,000	201,000

Capacity of 3″ Pipe Line, 3 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	80,000	61,000	....	....	....	....
5″—	106,000	93,000	70,000	....	....	....
Atmos. 0	131,000	121,000	104,000	77,000	....	....
Lb. per sq. in. 3	161,000	153,000	140,000	121,000	94,000	.....
6	191,000	184,000	173,000	159,000	139,000	102,000
10	230,000	224,000	216,000	204,000	189,000	164,000

These Tables are based on gas of .6 specific gravity.
For other specific gravities, apply multiplier found in Table, page 563.

Capacity of 3″ Pipe Line, 4 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	69,000	53,000	....	....	....	....
5″—	92,000	80,000	60,000	....	....	....
Atmos. 0	114,000	104,000	90,000	67,000	....	....
Lb. per sq. in. 3	140,000	132,000	121,000	105,000	81,000	....
6	165,000	159,000	150,000	138,000	120,000	89,000
10	199,000	194,000	187,000	177,000	164,000	142,000

Capacity of 4″ Pipe Line, 1 Mile Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	286,000	219,000	....	....	....	....
5″—	379,000	332,000	249,000	....	....	....
Atmos. 0	469,000	432,000	372,000	276,000	....	....
Lb. per sq. in. 3	577,000	547,000	501,000	435,000	336,000	....
6	683,000	658,000	621,000	568,000	497,000	366,000
10	824,000	803,000	773,000	731,000	677,000	588,000

These Tables are based on gas of .6 specific gravity.
For other specific gravities, apply multiplier found in Table, page 563.

Capacity of 4″ Pipe Line, 2 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	202,000	155,000	....	....	....	....
5″—	268,000	235,000	176,000	....	....	....
Atmos. 0	332,000	305,000	263,000	195,000	....	....
Lb. per sq. in. 3	408,000	387,000	354,000	308,000	237,000	....
6	483,000	465,000	439,000	402,000	351,000	259,000
10	582,000	568,000	546,000	517,000	479,000	416,000

Capacity of 4″ Pipe Line, 3 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	165,000	126,000	....	....	....	....
5″—	219,000	192,000	144,000	....	....	....
Atmos. 0	271,000	249,000	215,000	160,000	....	....
Lb. per sq. in. 3	333,000	316,000	289,000	251,000	194,000	....
6	394,000	380,000	358,000	328,000	287,000	211,000
10	476,000	464,000	446,000	422,000	391,000	340,000

These Tables are based on gas of .6 specific gravity.
For other specific gravities, apply multiplier found in Table, page 563.

Capacity of 4″ Pipe Line, 4 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	143,000	109,000	....	....	....	....
5″—	190,000	166,000	125,000	....	....	....
Atmos. 0	235,000	216,000	186,000	138,000	....	....
Lb. per sq. in. 3	288,000	273,000	251,000	217,000	168,000	....
6	342,000	329,000	310,000	284,000	248,000	183,000
10	412,000	402,000	386,000	366,000	339,000	294,000

Capacity of 4″ Pipe Line, 5 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	128,000	98,000	....	....	....	....
5″—	170,000	148,000	111,000	....	....	....
Atmos. 0	210,000	193,000	166,000	124,000	....	....
Lb. per sq. in. 3	258,000	245,000	224,000	194,000	149,000	....
6	306,000	294,000	278,000	254,000	222,000	164,000
10	368,000	359,000	346,000	327,000	303,000	263,000

These Tables are based on gas of .6 specific gravity.
For other specific gravities, apply multiplier found in Table, page 563.

Capacity of 6″ Pipe Line, 1 Mile Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	796,000	610,000	....	....	....	....
5″—	1,056,000	924,000	695,000	....	.....	.
Atmos. 0	1,307,000	1,203,000	1,037,000	770,000	....	....
Lb. per sq. in. 3	1,607,000	1,524,000	1,396,000	1,211,000	935,000	......
6	1,904,000	1,834,000	1,729,000	1,584,000	1,384,000	1,020,000
10	2,295,000	2,237,000	2,152,000	2,037,000	1,886,000	1,638,000

Capacity of 6″ Pipe Line, 2 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	563,000	431,000	....	....	....	....
5″—	747,000	654,000	491,000	....	....	....
Atmos. 0	924,000	851,000	733,000	661,000	....	....
Lb. per sq. in. 3	1,137,000	1,078,000	987,000	857,000	659,000	....
6	1,346,000	1,297,000	1,223,000	1,120,000	978,000	721,000
10	1,623,000	1,582,000	1,522,000	1,441,000	1,334,000	1,158,000

These Tables are based on gas of .6 specific gravity.
For other specific gravities, apply multiplier found in Table, page 563.

Capacity of 6″ Pipe Line, 3 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure. Inches of Mercury Minus Pressure.	Discharge Pressure. Inches of Mercury—Minus Pressure. 20″—	15″—	10″—	5″—	Atmosphere. 0	Lb. per sq. in. 3 lb.
10″—	459,000	352,000	....	....	....	....
5″—	610,000	534,000	401,000	....	....	....
Atmos. 0	755,000	695,000	599,000	445,000	....	....
Lb. per sq. in. 3	928,000	880,000	806,000	699,000	540,000	....
6	1,099,000	1,059,000	998,000	914,000	799,000	589,000
10	1,325,000	1,292,000	1,243,000	1,176,000	1,089,000	946,000

Capacity of 6″ Pipe Line, 4 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure. Inches of Mercury Minus Pressure.	Discharge Pressure. Inches of Mercury—Minus Pressure. 20″—	15″—	10″—	5″—	Atmosphere. 0	Lb. per sq. in. 3 lb.
10″—	398,000	305,000	....	....	....	....
5″—	528,000	462,000	347,000	....	....	....
Atmos. 0	654,000	602,000	518,000	385,000	....	....
Lb. per sq. in. 3	804,000	762,000	698,000	606,000	468,000	....
6	952,000	917,000	865,000	792,000	692,000	510,000
10	1,147,000	1,119,000	1,076,000	1,019,000	943,000	819,000

These Tables are based on gas of .6 specific gravity.
For other specific gravities, apply multiplier found in Table, page 563.

Capacity of 6″ Pipe Line, 5 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	356,000	273,000	....	....	....	...
5″—	473,000	413,000	311,000	....	....	......
Atmos. 0	585,000	538,000	464,000	344,000	....	......
Lb. per sq. in. 3	719,000	681,000	625,000	542,000	415,000	....
6	851,000	820,000	773,000	708,000	619,000	456,000
10	1,026,000	1,000,000	963,000	911,000	844,000	732,000

Capacity of 6″ Pipe Line, 6 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	325,000	249,000	....	....	....	....
5″—	431,000	377,000	284,000	....	....	....
Atmos. 0	534,000	491,000	423,000	314,000	....	......
Lb. per sq. in. 3	656,000	622,000	570,000	495,000	382,000	....
6	777,000	749,000	706,000	644,000	565,000	416,000
10	937,000	913,000	879,000	832,000	770,000	669,000

These Tables are based on gas of .6 specific gravity.
For other specific gravities, apply multiplier found in Table, page 563.

Capacity of 6″ Pipe Line, 8 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	281,000	216,000	....	....	....	....
5″—	373,000	327,000	246,000	....	....	....
Atmos. 0	462,000	425,000	367,000	272,000	....	....
Lb. per sq. in. 3	568,000	539,000	494,000	428,000	331,000	....
6	673,000	648,000	611,000	560,000	489,000	360,000
10	811,000	791,000	761,000	720,000	667,000	579,000

Capacity of 6″ Pipe Line, 10 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	252,000	193,000	....	....	....	....
5″—	334,000	292,000	220,000	....	....	....
Atmos. 0	413,000	380,000	328,000	243,000	....	....
Lb. per sq. in. 3	508,000	482,000	442,000	383,000	296,000	....
6	602,000	580,000	547,000	501,000	438,000	322,000
10	726,000	707,000	681,000	644,000	596,000	518,000

These Tables are based on gas of .6 specific gravity.
For other specific gravities, apply multiplier found in Table, page 563.

Capacity of 8″ Pipe Line, 1 Mile Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	1,659,000	1,271,000	....	....	....	....
5″—	2,202,000	1,927,000	1,448,000	....	....	....
Atmos. 0	2,725,000	2,507,000	2,161,000	1,605,000	....	....
Lb. per sq. in. 3	3,350,000	3,176,000	2,910,000	2,525,000	1,949,000	....
6	3,967,000	3,822,000	3,604,000	3,300,000	2,884,000	2,125,000
10	4,783,000	4,663,000	4,486,000	4,246,000	3,931,000	3,144,000

Capacity of 8″ Pipe Line, 2 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	1,173,000	899,000	....	....	....	....
5″—	1,557,000	1,362,000	1,024,000	....	....	....
Atmos. 0	1,927,000	1,773,000	1,528,000	1,135,000	....	....
Lb. per sq. in. 3	2,369,000	2,246,000	2,058,000	1,786,000	1,378,000	....
6	2,805,000	2,702,000	2,548,000	2,334,000	2,039,000	1,503,000
10	3,382,000	3,297,000	3,172,000	3,003,000	2,780,000	2,414,000

These Tables are based on gas of .6 specific gravity.
For other specific gravities, apply multiplier found in Table, page 563.

Capacity of 8″ Pipe Line, 3 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	958,000	734,000	....	....	....	....
5″—	1,271,000	1,112,000	836,000	....	....	....
Atmos. 0	1,573,000	1,448,000	1,248,000	927,000	....	....
Lb. per sq. in. 3	1,934,000	1,834,000	1,679,000	1,458,000	1,125,000	....
6	2,291,000	2,206,000	2,081,000	1,905,000	1,665,000	1,227,000
10	2,762,000	2,692,000	2,590,000	2,452,000	2,270,000	1,971,000

Capacity of 8″ Pipe Line, 4 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	829,000	636,000	....	....	....	....
5″—	1,101,000	963,000	724,000	....	....	....
Atmos. 0	1,362,000	1,254,000	1,081,000	802,000	....	....
Lb. per sq. in. 3	1,675,000	1,588,000	1,455,000	1,262,000	975,000	....
6	1,984,000	1,911,000	1,802,000	1,650,000	1,442,000	1,063,000
10	2,392,000	2,331,000	2,243,000	2,123,000	1,966,000	1,707,000

These Tables are based on gas of .6 specific gravity.
For other specific gravities, apply multiplier found in Table, page 563.

Capacity of 8″ Pipe Line, 5 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	742,000	568,000	....	....	....	....
5″—	985,000	862,000	647,000	....	....	....
Atmos. 0	1,218,000	1,121,000	967,000	718,000	....	....
Lb. per sq. in. 3	1,498,000	1,420,000	1,302,000	1,129,000	865,000	....
6	1,774,000	1,709,000	1,612,000	1,476,000	1,290,000	950,000
10	2,139,000	2,085,000	2,006,000	1,899,000	1,758,000	1,525,000

Capacity of 8″ Pipe Line, 6 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	677,000	519,000	....	....	....	....
5″—	899,000	786,000	591,000	....	....	....
Atmos. 0	1,112,000	1,024,000	882,000	655,000	....	....
Lb. per sq. in. 3	1,367,000	1,297,000	1,188,000	1,031,000	796,000	....
6	1,620,000	1,560,000	1,471,000	1,341,000	1,178,000	868,000
10	1,953,000	1,904,000	1,832,000	1,734,000	1,605,000	1,394,000

These Tables are based on gas of .6 specific gravity.
For other specific gravities, apply multiplier found in Table, page 563.

Capacity of 8″ Pipe Line, 8 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	586,000	449,000	....	....	....	....
5″—	778,000	681,000	512,000	....	....	....
Atmos. 0	963,000	886,000	764,000	567,000	....	....
Lb. per sq. in. 3	1,184,000	1,123,000	1,029,000	893,000	689,000	....
6	1,403,000	1,351,000	1,274,000	1,167,000	1,020,000	751,000
10	1,691,000	1,649,000	1,586,000	1,501,000	1,390,000	1,207,000

Capacity of 8″ Pipe Line, 10 Miles Long, for 24 Hours at "Vacuum" or Minus Pressure.

Intake Pressure.	Discharge Pressure.					
Inches of Mercury Minus Pressure.	Inches of Mercury—Minus Pressure.				Atmosphere.	Lb. per sq. in.
	20″—	15″—	10″—	5″—	0	3 lb.
10″—	524,000	402,000	....	....	....	....
5″—	696,000	609,000	458,000	....	....	....
Atmos. 0	862,000	793,000	683,000	507,000	....	....
Lb. per sq. in. 3	1,059,000	1,004,000	920,000	798,000	616,000	....
6	1,255,000	1,208,000	1,140,000	1,044,000	912,000	672,000
10	1,513,000	1,475,000	1,419,000	1,343,000	1,243,000	1,080,000

These Tables are based on gas of .6 specific gravity.
For other specific gravities, apply multiplier found in Table, page 563.

Multipliers to be Used for Gas of Specific Gravities Other than .6.

.6	1.00	1.20	.707
.65	.96	1.25	.692
.7	.925	1.30	.679
.75	.894	1.35	.666
.8	.866	1.40	.654
.85	.84	1.45	.643
.9	.816	1.50	.632
.95	.794	1.55	.622
1.0	.774	1.60	.612
1.05	.755	1.65	.603
1.10	.738	1.70	.594
1.15	.722	1.75	.585

Measuring Gasoline Gas—When gasoline gas is purchased by the cubic foot it is necessary to provide some means of securing an accurate measurement of it. A large capacity dry meter is built for this character of work whether the gas measured is under pressure or at a minus pressure commonly spoken of as a "vacuum."

It is only necessary to keep the meter clean and note the condition of the diaphragms from time to time. The heavy gas has a tendency to dry out the leather diaphragm quicker than in measuring any other kind of gas.

If the gas is at a minus pressure the recording volume and vacuum gauges are necessary.

In installing meters for this work it is essential to set the meter far enough away from the compressor so that the

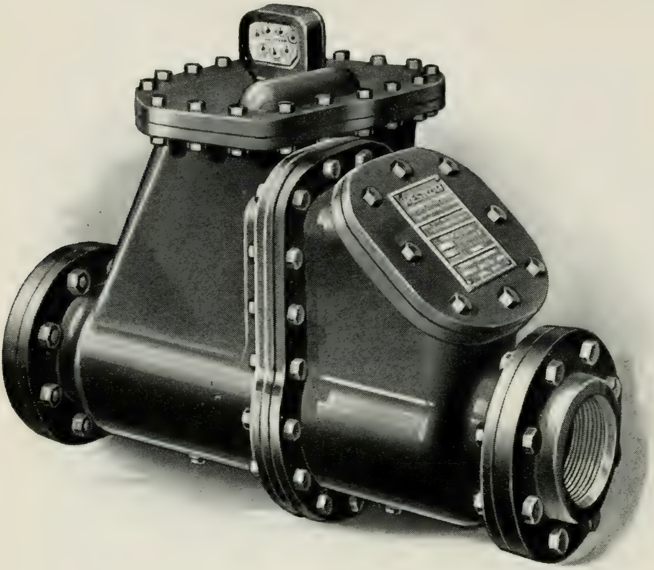


Fig. 226—A LARGE CAPACITY METER SPECIALLY BUILT TO MEASURE GASOLINE GAS

suction of the piston will not be felt in the meter. This can be done by utilizing a series of large pipe coils directly adjoining the compressor building between the compressor and the meter without creating any appreciable increased friction due to additional pipe. The greater the area of the pipe the less will be the number of coils necessary to overcome the vibration in the meter. To determine the presence or absence of vibration, attach a mercury or spring gauge to the meter and if the mercury or gauge hand vibrates the effects of the piston in the compressor have not been eliminated. In this case, either place the meter further from the station or increase the coils.

All gas lines leading to the compressor should be buried. If possible lay through wet ground or creeks. This method assists in preventing condensation of gasoline in lines before it passes through compressor, where provision is made for trapping it.

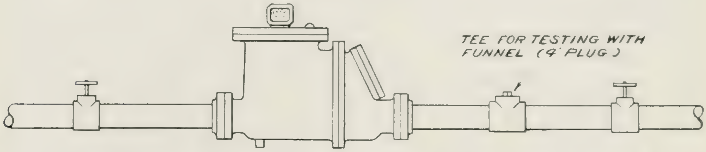


Fig. 227—INSTALLATION OF A LARGE CAPACITY METER FOR MEASURING GASOLINE GAS

Table to Determine the Proper Size Meter in Measuring Gas at a "Vacuum" or Minus Pressure, in Inches of Mercury, where the Maximum Volume per 24 Hours or per Hour is Given at Four Ounces Pressure Above an Atmospheric Pressure of 14.4 Lb. per Square Inch.

Maximum Volume Per 24 Hours	Maximum Volume per Hour	Capacity of Meters at Different Pressures in Cu. Ft. per Hour			
		5″	10″	15″	20″
50,000	2,080	3M	3M	6M	10M
100,000	4,160	6M	10M	10M	20M
150,000	6,250	10M	10M	20M	20M
200,000	8,330	10M	20M	20M	35M
250,000	10,410	20M	20M	20M	35M
300,000	12,500	20M	20M	35M	50M
400,000	16,660	20M	35M	35M	50M
500,000	20,830	35M	35M	50M	75M
600,000	25,000	35M	50M	50M	75M
800,000	33,330	50M	50M	75M	100M
1,000,000	41,660	50M	75M	100M	125M
1,500,000	62,500	75M	100M	125M	*200M
2,000,000	83,300	100M	125M	*200M	*275M

*Means use two or more meters in battery form.

Volume and Pressure Recording Gauge—This type of gauge is fully described and illustrated, see figure number 153 on page number 383. It is of great assistance in measuring gasoline gas at various plus or minus pressures.

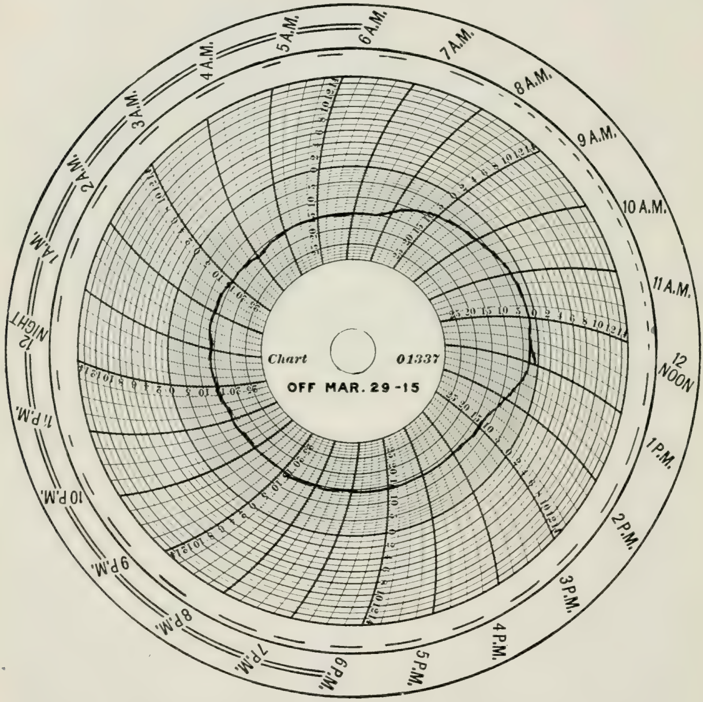


Fig. 228—VOLUME AND PRESSURE RECORDING GAUGE CHART

One great advantage in the use of a pressure and volume recording gauge when used on a large capacity meter in measuring gasoline gas is fully illustrated in the cut number 228.

In this instance the meter was installed on a six-inch line leading from an oil lease to the main compressor station.

The compressor was using residue gas for fuel and during the morning of the 28th (the chart was removed on the 29th) the engineer noticed that the engine was "getting air." On visiting the nearby meters the source of trouble was soon located and remedied. It was discovered that the line on which this meter and gauge were located had been broken and the compressor was "getting air" through this meter. The pressure on the oil wells at the end of this line was about 12 inches mercury minus pressure or vacuum when being pumped, and as the atmosphere was about 29.5 inches mercury pressure naturally this higher pressure caused the meter readings to jump up and the compressor to pump more air than it did gas at the lower pressure through this line.

As each dash on the chart indicated a volume of 10,000 cubic feet, approximately 160,000 cubic feet of air meter reading had passed the meter which without the pressure and volume recording gauge would have been paid for at five cents per thousand. With this type of gauge the gasoline company could show just when the break occurred, when it was repaired and how much meter reading should be deducted in making settlement for gasoline gas at the end of the month from that particular lease.

Condensation in Meters—As gasoline gas is a combination of natural gas and higher hydrocarbons in a gaseous state, all that is needed to cause condensation is that the temperature of the flowing gas be lower than the temperature of the metal that confines it. As gas flows through a pipe line it has the tendency of giving or taking the same temperature as the pipe line. But as it enters a meter or drip the velocity of gas decreases, due to the enlarged size of same and as the meters or drips are generally above the ground there is greater opportunity for condensation of higher hydrocarbons than in a pipe line. The fact is where a pipe line is buried and the meter exposed in the open, the meter acts, in cold weather, as a cooler or radiator to the gas. This

condition often causes considerable condensation which interferes with the accuracy of the meter unless precautions are taken.

To overcome this there are two remedies. One is to place a torch or heater back of the inlet of the meter (at a safe distance) and to warm the gas enough so that the meter will also have a warm temperature. The other is to cover the line and meter with manure which will give the meter the same temperature as the pipe line.

Either of the above will prevent condensation of the higher hydrocarbons and greatly assist in accurately measuring the gas.

Testing Large Capacity Meters with Gasoline Gas—In testing with the funnel meter use the residue gas. Take the specific gravity of the gas every three or four hours while testing, even though working on one meter. It is commonly found that the gravity of the residue gas will run as high as 1.1 even after the gasoline has been extracted. This is due to the fact that while the very highest hydro-carbons have been extracted they evaporate and pass out with the residue gas. The gravity of the residue gas will be highest in warm weather.

Greater caution should be used in testing with this gas than with natural gas as the residue gas being so heavy will lay near the ground and not raise. Do not run any tests within a building.

Construction of Gasoline Plant—If the range of pressures through which the gas is to be compressed exceeds seven or eight compressions, it is necessary to use a two-stage compressor in order to keep the temperature within proper working limits. For this class of work a single two-stage unit, with an intercooler forming a part of it, is satisfactory.

It is also desirable to have the compressor belt-driven, to permit of housing it in a separate building minimizing the danger. An added precaution can be taken by having the compressor rods packed off with double stuffing boxes provided with a vent pipe leading out of the building, in order to prevent the escape of the highly inflammable gas into the room in case of any leak due to defective packing.

Gas engines utilizing residual dry gas as a fuel, furnish an ideal motor power, and an excellent method of transmitting the power from engine to compressor is by means of belting, through a counter shaft. This permits of operating both engine and compressor at the proper speeds to secure highest economy from both, and furnishes a convenient means of driving such small machine tools as may be needed about the plant, such as lathe, drill press and electric light dynamo.

After the gas is compressed, it is passed through the water cooling coils; thence into the expansion cooling coils, where it is rendered very cold while still at a high pressure by means of the expansion of dry gas from which the gasoline had previously been extracted. This extraction of heat while under high pressure causes the gasoline vapors to condense, and the gas and liquid are then passed into the separating tanks, where the velocity of the gas is greatly reduced and the gasoline separated from it. The dry gas then passes out into the expansion nozzle of the expansion cooling coils, and takes its turn in expanding from a high to a low pressure, thus cooling the compressed gas that passed through the compressor and water cooling system after it did. It is then piped away into dry gas lines to be used as fuel for the gas engines and for any other purpose desired.

The safest ignition system to use on gas engines is the make and break system, furnished with current from storage batteries, the latter being charged at night from the electric light system.

Water, of course, has to be used to keep the gas engine cool and to cool the compression cylinders of the compressor, but only a very small quantity is necessary for this purpose and it can be circulated indefinitely.

It is necessary for the successful operation of a plant that the stock and making houses be built of cement in order to exclude the heat, so far as possible, during the hot season. Gasoline is so very volatile that heat produces a high pressure in the storage tanks.

Description of Ordinary Ammonia Refrigerating Machine (from Bulletin 88, Bureau of Mines)—"An ordinary ammonia refrigerating machine, such as is used for cooling purposes, in general consists essentially of three parts—a refrigerator or evaporator, a compression pump and a condenser.

The refrigerator, which consists of a coil or a series of coils, is connected to the suction side of the pump, and the delivery from the pump is connected to the condenser, which is generally of a somewhat similar construction to the refrigerator. The condenser and the refrigerator are joined by a pipe in which is a valve called the regulator. Outside the refrigerating coils is the air, brine, or other substance that is to be cooled in the refrigeration system; and outside the condenser is the cooling medium, which is water. The liquid ammonia passes from the bottom of the condenser through the regulating valve into the refrigerator in a continuous stream. As the pressure in the refrigerator is reduced by the pump and maintained at such a degree as to give the desired boiling point—which is, of course, always lower than the temperature outside the coils—heat passes from the substance outside through the coil surfaces and is taken up by the entering liquid, which is converted into vapor. The vapors thus generated are drawn into the pump, compressed, and discharged into the condenser, the temperature of which is somewhat above that of the cooling water. Heat is

transferred from the compressed vapor to the cooling water, and the vapor is converted into a liquid which collects at the bottom and returns by the regulating valve into the refrigerator. The compressor may be driven by a gas engine or in any other convenient manner. The pressure in the condenser varies according to the temperature of the cooling water, and that in the refrigerator is dependent upon the temperature to which the outside substance is cooled.

Anhydrous ammonia is a gas at ordinary temperatures and under atmospheric temperatures. The liquid anhydrous ammonia is commercially sold in iron drums in which it is contained under a pressure varying between 120 and 200 pounds per square inch, the pressure in the drum depending on the temperature of the liquid in it.

Some idea of the nature of the natural gas condensate obtained can be had by considering the liquefaction points of the constituents that are found in natural gases used for gasoline condensation. The boiling point of liquid propane is — 45° C. (—49° fahr.), and of liquid butane 1° C. (34° fahr.).

The lowest temperature obtained in the refrigerating coils of the Olinda plant is — 10° C. (14° fahr.). Hence it can be accepted that no propane is liquefied, but some butane and higher paraffins are. The efficiency of the extraction of the condensible constituents from the natural gas for any given temperature will depend upon the velocity of the gas through the coils, or, what is the same thing, the area of cooling surface. Heat is of course extracted from the natural gas when it enters the cooling system. If the cooling area of the pipes is not great enough, the residual natural gas will leave the system still containing gasoline vapors that could have been condensed by further cooling treatment. By proper experimentation the amount of cooling surface required to produce the greatest quantity of salable condensate can be ascertained. Presumably the operators of the Olinda

plant have made such a determination. The authors are not closely aquainted with the operations. They believe that the refrigeration method offers much promise and that more plants of this type will be installed.

In the United States at least 85 per cent. of the refrigeration plants used for various purposes use ammonia as the refrigerant. Other refrigerants that may be used are sulphur dioxide, carbon dioxide, and water vapor."

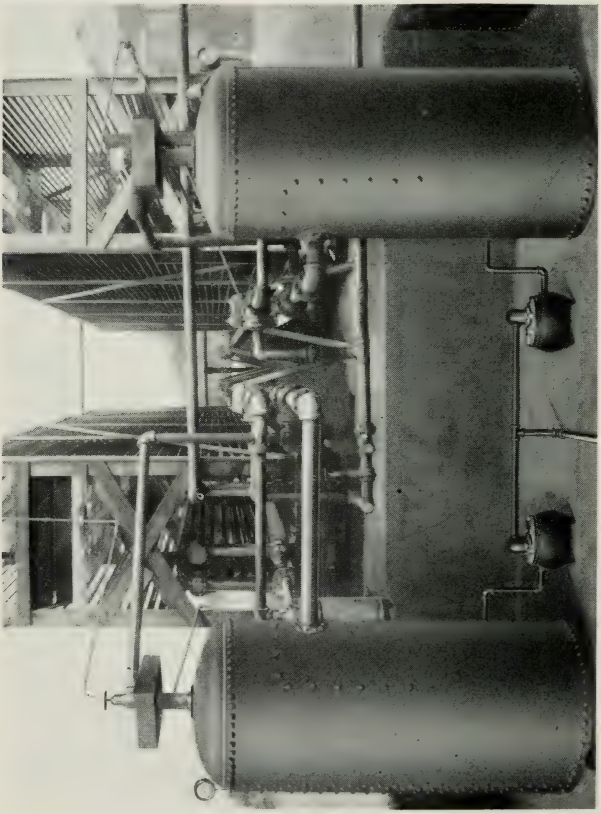


Fig. 229.—GASOLINE PLANT SHOWING COILS AND TANKS

Lighting Plant—While there is danger of explosion due to the breaking of an incandescent light bulb in an explosive mixture of gas and air, nevertheless the electric light furnishes the least dangerous method of lighting a gasoline-gas plant and should invariably be used. Good ventilation should always be provided to prevent the accumulation of gas, and all light bulbs should be guarded to prevent breakage.

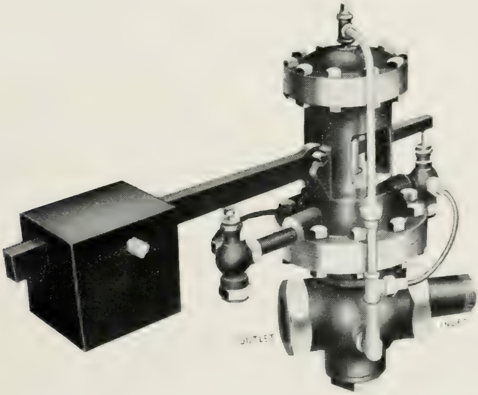


Fig. 230—GAS RELIEF VALVE OR REGULATOR FOR NATURAL GAS GASOLINE PLANTS

Gas Relief Regulator—This regulator is of special interest to gasoline makers.

After the gasoline has been compressed to a high pressure, generally about three hundred pounds, per square inch, this type of regulator will reduce the pressure to twenty or thirty pounds and retain that pressure. If the pressure ahead of the regulator drops below that at which it is set, it will cut off. In other words it acts the opposite of a standard regulator used in distributing gas.

Percentage of Vapor Condensed by Compression and Cooling (from Bulletin 88, Bureau of Mines)—"The change in the raw gas that takes place in the compressors and coolers of a plant consists in the conversion of certain vapors and

gases into liquid condition, and the solution of gases in these liquids. To give exact figures for the proportions of gas and vapor that disappear is impossible. An approximation, however, can be reached. One gallon of liquid propane when converted into gas produces about 31 cubic feet of gas at 0° C. and 760 mm. pressure. One gallon of propane in the liquid condition produces about 45 cubic feet of gas. One gallon of butane produces 37 cubic feet of gas. Butane and pentane are probably the two paraffins that are removed in greatest quantity.

Aside from such liquefaction a certain amount of gas is absorbed by the liquid, as stated above. It is small as regards the total disappearance of gas. The authors estimate that at some plants about 35 cubic feet of gas disappears for each gallon of condensate produced from 1,000 cubic feet of gas. If 4 gallons of condensate per 1,000 cubic feet of gas is obtained, then 140 cubic feet, or about 14 per cent of the gas treated, has disappeared. At some plants, however, as much as 50 per cent of gas disappears, and at others the quantity of residual gas is almost insignificant.

Results of Analyses of Gases from Different Stages of Plant Operation—Table following shows the results of laboratory tests of various gases derived from the different stages of plant operation. The percentage of air was calculated from the oxygen content as determined by analysis.

Regarding the results shown in table on page 572, the chemical analysis, the specific gravity determination, and the claroline oil absorption show the gas represented to be a rich one. It will be seen that little difference existed between the composition of the crude gas and the same gas after it had been compressed to a pressure of 50 pounds per square inch. Only after the compression to a pressure of 250 pounds per square inch and cooling, did the composition of the gas mixture change appreciably.

RESULTS OF LABORATORY TESTS OF SAMPLES OF GAS FROM DIFFERENT GASOLINE PLANTS (Bureau of Mines—Paper No. 88)

PLANT NEAR FOLLANSBEE, W. VA.

Condition of gas	Cal. gross heating value per cu. ft. at 0°C. and 760 mm.	Specific Gravity at 0°C. and 760 mm. (air=1.)	Proportion absorbed by 35 cc. of oil.	Composition								Remarks
				Air	CH_4	C_2H_6	C_3H_8	C_4H_{10}	N_2	CO_2	Total	
	B.t.u.			*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*	
Natural gas as drawn from the well	2,544	1.46	85.7	.....	.....	10.8	88.3	.....	0.9	.....	100	The gas was drawn from 75 producing oil wells, under a reduced pressure of 20 inches of mercury.
Residual gas after removal of 50 pounds of compression product	2,515	1.46	.....	.....	.....	16.9	82.9	.....	0.2	.....	100	The gasoline produced was shipped in drums to Pittsburgh, Pa., where it was blended with refinery naphtha for the market.
Residual gas after removal of 250 lb. of compression product	2,171	1.23	78.2	.....	.....	59.2	40.3	.....	0.5	.....	100	
Natural gas as drawn from the well	2,474	1.41	83.6	.....	.....	21.4	78.2	.....	.4	.....	100	These samples were taken from the same plant as those above, but were taken two months previous.
Residual gas after removal of 50 pounds of compression product	2,415	1.38	82.0	.....	.....	26.5	72.4	.....	1.1	.....	100	
Residual gas after removal of 250 pounds of compression product	2,022	1.15	63.6	.....	.....	77.3	22.0	.....	.7	.....	100	

Under existing methods of plant operation, condensate is extracted from natural gas that ranges in specific gravity from as low as 0.83 to as high as 1.59 (air = 1) and the solubilities of the gas in claroline oil ranges from 36.9 (air free) to 85.7 per cent, according to the well from which it comes.

The authors hesitate to recommend the installation of a plant to handle natural gas that shows results as poor as the minimum values given in the table. Such gas might produce gasoline in paying quantities and might not. Probably the safest extremes would be a specific gravity of 0.95 (air = 1), and a claroline-oil absorption of 40 per cent. The natural gas supplied to Pittsburgh, Pa., with which the authors are most familiar, contains little of the gaseous hydrocarbons, has a specific gravity of 0.64 (air = 1), and has a claroline-oil absorption of about 16 per cent. It is a dry gas and is unsuitable for gasoline production.

Specific Gravities and Absorption Numbers of Natural Gases Used for Condensation of Natural Gas (Bureau of Mines, Bulletin No. 88. By G. A. Burrel, F. M. Seibert and G. G. Oberfell)—The authors have compiled the following table to show at a glance the specific gravities and absorption numbers of natural gases used for the condensation of natural gas. The table is compiled from the results shown in the table preceding. The compilation will be useful for reference in predicting the results that may be obtained from other samples of natural gas.

No.	Specific gravity (air=1)	Absorption number	No.	Specific gravity (air=1)	Absorption number
1........	1.46	86	7........	1.37	48
2........	1.41	84	8........	1.38	44
3........	1.03	39	9........	1.21	54
4........	1.59	43	10........	1.29	50
5........	.83	23	11........	1.07	38
6........	1.38	65	12........	1.00	37

LOW EXPLOSIVE LIMITS FOR PARAFFIN GASES AND VAPORS. [a] (Bureau of Mines)

The following table shows the small percentages of gases and vapors occurring in natural gas that are required to form explosive mixtures with air:

Hydrocarbon	Proportion of gas-air mixture constituting low explosive limit	Hydrocarbon	Proportion of gas-air mixture constituting low explosive limit
	Per cent.		*Per cent.*
Methane	5.60 to 5.70	N butane	1.60 to 1.70
Ethane	3.00 to 3.20	N pentane	1.35 to 1.40
Propane	2.15 to 2.30		

According to the above table, even if a natural gas consisted almost entirely of methane, as some natural gases do, an explosion would follow an ignition of a mixture of air and natural gas containing 5.50 per cent. of methane.

Solution of Gas in Condensates—As previously stated, one of the physical changes occurring in the operation of a gasoline plant has to do with the solution of gas in the condensate, that is, when the residual gas is in contact with the condensate in the storage tank. The following experiment and calculation by the authors will serve to show how small and insignificant this change may be.

A residual gas from an operating plant was shaken with refinery naphtha. The naphtha had a specific gravity of 61° B. The solution was effected at a temperature of 20° C. (68° fahr.) and atmospheric pressure. The naphtha was shaken with the gas supply until no more gas would go into solution. It was found that 1 liter of the naphtha dissolved

[a] Burgess, M. J., and Wheeler, R. V., The lower limit of the inflammability of mixtures of the paraffin hydrocarbons with air; Trans. Chem. Soc., vol. 99, 1911, pp. 2013, 2030.

1,760 liters of the gas; or 500 gallons of the naphtha would have dissolved 3,331.7 liters of the gas. If the assumption be made that this residual gas was ethane only, then it can be calculated that 3,331.7 liters of gaseous ethane at 16° C. (60° fahr.) and 30 inches of mercury is equivalent to 2.7 gallons of liquid ethane. This quantity of liquid is so small as to seem insignificant, although as regards raising the vapor pressure of the condensate it is important.

Evaporation Losses in Blending—The following table shows the results of some blending tests made by the authors. The condensate, as it was drawn from the storage tank, was allowed to stand in graduated vessels, and the loss sustained by evaporation over different periods of time was noted. The containers were graduated glass cylinders having a capacity of 1,000 c. c. Their inside diameter was 2⅜ inches and they were 13 inches high. Some of the same condensate, as it was drawn from the storage tanks, was also mixed with naphtha and allowed to stand and the loss noted."

EVAPORATION LOSSES OF DIFFERENT MIXTURES OF NATURAL GAS CONDENSATES AND REFINERY NAPHTHAS

Test No.	Proportions in mixture		Specific gravity of—		Specific gravity of mixture.	End of 1 hour		End of 2 hours	
	Condensate	Naphtha	Condensate	Naphtha		Specific gravity	Loss	Specific gravity	Loss
	P. ct.	*P. ct.*	*°B.*	*°B.*	*°B.*	*°B.*	*Per ct.*	*°B.*	*Per ct.*
1......	50	50	93	60	76.5	76	4	75	10
2......	70	30	93	44	76	75.5	6	74.5	14
3*a*.....	70	30	95	44	74.5	74	13	72.5	20
4*a*.....	50	50	95	44	67	65.5	8	65	16

Test No.	End of 3 hours		End of 4 hours		Proportions in mixture		Specific gravity of—		Specific gravity of mixture
	Specific gravity	Loss	Specific gravity	Loss	Condensate	Naphtha	Condensate	Naphtha	
	°B.	P. ct.	°B.	P. ct.	P. ct.	P. ct.	°B.	°B.	°B.
1......	75	12	74	16	50	50	93	60	76.5
2......	73.5	20	72.5	24	70	30	93	44	76
3*a*......	72	26	71.5	29	70	30	95	44	74.5
4*a*......	64	20	64	22	50	50	95	44	67

Test No.	End of 5 hours		End of 6 hours		End of 7 hours		End of 24 hours		Temperature of atmosphere	
	Specific gravity	Loss	Specific gravity	Loss	Specific gravity	Loss	Specific gravity	Loss		
	°B.	P. ct.	°B.	P. ct.	°B.	P. ct.	°B.	P. ct.	°fahr.	°C.
1....	74	18	73	22	70.5	31	67	43	65to70	18to21
2....	71.5	29	71	30	.....	.....	.....	.....	....	....
3*a*...	71	30	69	34	68.5	37	65	50	60to70	16to21
4*a*...	63	25	62	30	61	36	56	54	60to70	16to21

Hauling Gasoline—In some cases where high gravity gasoline is hauled in drums by wagons, it is good policy to cover the load well with wet blankets. The blankets can be drenched with water en route at any convenient watering place. This method will keep the gasoline cool and insure safe delivery, especially in warm weather.

a In conducting this test the mixture was exposed to the atmosphere to a greater extent than in tests 1 and 2. It was poured from one vessel to another eight times, thus exposing more liquid surface to the atmosphere and causing more rapid evaporation than would have occurred if it had been allowed to remain in the the same vessel all time without disturbance.

Market for High Gravity Gasoline—There is a large demand for gasoline of 88 deg. Beaume test by canning factories for soldering, by plumbers and tinsmiths, and for burning off paint from buildings by painters. Racing automobiles also use it for power.

PRESSURES GENERATED BY HEATING GASOLINE AND CONFINED LIQUEFIED NATURAL GAS

(By C. A. Burrell)

Temperature		Pressures Generated by—			
		Refinery gasoline (80°B.)	Natural Gasoline Obtained at—		
			50 pounds pressure	250 pounds pressure	400 pounds pressure
°C.	°*Fahr.*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
0	32	0	. .	107	360
5	41	0	9	117	375
10	50	0	12	130	398
15	59	0	16	144	423
20	68	3	20	154	453
25	77	5	25	175	482
30	86	10	30	193	510
35	95	16	34	210	545
40	104	26	40	231	585
45	113	41	46	251	630
50	122	92	52	275	690
55	131	350	58	. . .	755
60	140	. . .	65	. . .	. . .

TABLE OF HEAT VALUES OF THE LIGHTER HYDRO-CARBON PRODUCTS FROM CRUDE OIL

Commercial Term	Beaume	B. t. u. per lb.	B. t. u. per Standard U. S. Gallon
Gasoline	100	22,250	
	95	22,050	
	90	21,850	115,805
	85	21,650	117,343
	80	21,450	119,476
	76	21,290	120,927
	75	21,250	121,337
	73	21,170	122,150
	70	21,050	123,142
	68	20,970	123,932
	65	20,850	125,100
	64	20,810	125,484
	62	20,730	126,453
	58	20,570	127,945
Kerosene: (Water White)	48	20,170	132,516
	46	20,090	133,397
	44	20,010	134,467
	42	19,930	135,524
	40	19,850	136,369

A gallon of 65 deg. gasoline, which weighs 5.999 pounds, will produce 22.7 cubic feet of gas; and one gallon of 70 deg. gasoline, weighing 5.85 pounds, will produce 23.1 cubic feet of gas. Temperature 60 deg. fahr.

Effects of Different Weather Conditions on the Manufacturing of Gasoline—In dry hot weather it is difficult to obtain adequate cooling water and as a consequence the production of gasoline is smaller than during the cold winter months.

Operating Cost—The cost of operating a plant capable of making seven hundred gallons of gasoline per day should not exceed $15 per day including everything, and can be installed for $10,000 complete. Since there is a ready market for gasoline, it is easy to appreciate that there should be a good profit in it.

Shipping Gasoline—Wooden barrels should not be used to ship gasoline extracted from natural gas. Steel drums of the very best type manufactured should be used and must stand a pressure of forty pounds per square inch without any leaks whatever. A fifty-five gallon drum should weigh not more than seventy pounds without hoops and a one-hundred-and-ten gallon drum should weigh not less than one hundred and thirty pounds without hoops.

If a drum, such as is used for shipping gasoline and high distillates, filled with 64 deg. Beaume gasoline is allowed to stand in the sun with the thermometer registering 95 deg. fahr. with a pressure gauge attached, it will show that the heat has caused a gas pressure of twenty-nine and one-half pounds. For the purpose of transporting gasoline, special drums have been designed to withstand over eighty pounds pressure.

Do not use wooden plugs. Metal plugs should be close fitting, using a gasket of asbestos.

Glycerine drums are not satisfactory holders of gasoline.

Drums should not be filled full, but only to within about two inches of the top, to allow for expansion.

Safety Valves for Gasoline Tank Cars—Safety valves on tank cars should be set to blow off at ten pounds. It is better

to use several safety valves set at ten, fifteen, twenty, and twenty-five pounds than to use one valve set at ten pounds.

Rules of the Interstate Commerce Commission—The final rules of the Interstate Commerce Commission regarding the shipment of natural gas gasoline are presented below:

Regulations for the Transportation on Railroads of Natural Gas Gasoline *a*—Liquefied petroleum gas is a condensate from the "casing-head gas" of petroleum oil wells, whose vapor tension at 100° fahr. (38° C.) (90° fahr. or 32° C. —November 1 to March 1) exceeds 10 pounds per square inch. Liquefied petroleum gas must be shipped in metal drums or barrels which comply with "Shipping-Container Specifications No. 5," or in tank cars especially constructed and approved for this service by the Master Car Builders' Association.

When the vapor tension at 100° fahr. (38° C.) exceeds 25 pounds per square inch, cylinders as prescribed for compressed gas must be used.

(The Commission has not deemed it best at this time to prohibit the use of good wooden barrels in shipping inflammable liquids with a flash point below 20° fahr. (—7° C.) It is, however, expected that their use for that purpose will be gradually discontinued and that within a reasonable time metal barrels will come into general use for such shipments.)

Packages containing inflammable liquids must not be entirely filled. Sufficient interior space must be left vacant to prevent distortion by containers when heated to a temperature of 120° fahr. (49° C.). This vacant space must not be less than 2 per cent. of the capacity of the container including the dome capacity of tank cars.

1. The provisions of "Shipping-Container Specifications No. 5" apply to all containers specified therein that are

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a From "Regulations of the Interstate Commerce Commission for the Transportation of explosives and other Dangerous Articles by Freight and by Express, and Specifications for Shipping Containers," published by the Bureau for the Safe Transportation of Explosives and Other Dangerous Articles, in January, 1912, pp 72, 143, 144, and 145. Effective March 31, 1912.

purchased after December 31, 1911, and used for the shipment of dangerous articles other than explosives. Each such container purchased subsequently to December 31, 1911, shall have plainly stamped thereon the date of manufacture thereof.

2. An iron or steel barrel or drum with a capacity of from 50 to 55 gallons must have a minimum weight in the black, exclusive of the weight of rolling hoops, of 70 pounds, and the minimum thickness of metal in any part of the completed barrel must not be less than that of No. 16 gauge United States standard.

3. An iron or steel barrel or drum with a capacity of from 100 to 110 gallons must have a minimum weight in the black, exclusive of the rolling hoops, of not less than 130 pounds, and the minimum thickness of metal in any part of the completed barrel or drum must not be less than that of full No. 14 gauge United States standard.

4. Each barrel or drum must stand without leaking a manufacturers' test under water by interior compressed air at a pressure of not less than 15 pounds per square inch sustained for not less than two minutes, and the type of barrel or drum must be capable of standing without any serious permanent deformation and without leaking a hydrostatic test pressure of not less than 40 pounds per square inch, sustained for not less than five minutes.

5. When filled with water to 98 per cent. of its capacity the type of barrel or drum must also be capable of standing without leakage a test drop on its chime for a height of 4 feet upon a solid concrete foundation.

6. Bungs and other openings must be provided with secure closing devices that will not permit leakage through them. Threaded metal plugs must be close fitting. Gaskets must be made of lead, leather, or other suitable material. Wooden plugs must be covered with a suitable coating and must have a driving fit into a tapered hole.

7. The method of manufacturing the barrel or drum and the materials used must be well adapted to producing a uniform product. Leaks in a new barrel or drum must not be stopped by soldering, but must be repaired by the method used in constructing the barrel or drum.

Liquefied Gas: A By-Product from Gasoline Gas *(By Walter O. Snelling)*—"During the past few years some promising work has been done toward the production of pure homogeneous liquid products from natural gas, suitable for the cheap and convenient lighting of isolated dwellings. Efforts have been made for many years to utilize compressed natural gas as a means of lighting, and cases are known where cylinders of compressed natural gas have been so used and in the near vicinity of natural gas fields, but outside of the range of popular distribution. The pressures which result from the compression of natural gas are, however, very considerable. The average steel cylinder used in the distribution of compressed oxygen, for example, has an actual capacity usually ranging from three-fourths cubic foot to one cubic foot. Upon compressing up to 100 volumes of natural gas in such a cylinder the pressure reaches 100 atmospheres, or 1,500 pounds per square inch, and it is of course wholly impossible for cylinders holding as little as 100 cubic feet of natural gas to be utilized commercially. These two experiments in the compression of natural gas were the forerunners of a series of experiments made toward liquefying the higher members of the paraffin series present in oil-well gases, and as a result of these studies a method has been devised by which there is now being prepared commercially a liquefied natural gas, known under the trade name of "Gasol," and which seems destined to have an important part in the solution of the problem of the lighting of isolated dwellings.

Realizing that the simple compression of natural gas would not produce a product which could be commercially

handled on account of the high pressure present in the container, efforts were directed toward separating as a homogeneous and pure material the ethane and propane present in the heavier or "wet" gases from oil wells. The simple compression of such material produces a condensation of all the hydrocarbons present, including hexane and pentane, and considerable quantities of ethane, propane and butane. Preliminary experiments were made to utilize this condensate, but the fact that it was entirely lacking in homogeneity, and that the gases given off in its volitalization were different from moment to moment, showed such a plan to lack feasibility. As a result of an extended series of studies, we succeeded in 1911 in preparing pure products of ethane and propane, these having been separated from natural gas condensates by a system of fractionation based on selective condensation on heated oils. The principle involved in the separation of these pure products consists primarily in the vaporization of all of the hydrocarbons present under a very high pressure, usually from 800 to 1,000 pounds per square inch, and while under this high pressure condensation is effected upon coils which are heated intermediate between the critical temperature of part of the gases present. As a result it was found possible to entirely separate hexane and pentane from the ethane and propane, and to liquefy the ethane and propane in separate containers.

The commercial preparation of the new gas involves the compression of "wet" natural gas, with consequent liquefaction of a large part of the hydrocarbons contained, the separation of the more easily condensed products, particularly hexane and higher isomers, and the rectification of the remaining product by means of selective condensation upon heated coils while the gas is under high pressure, usually in excess of 1,000 pounds per square inch. The heated coils are maintained at such temperatures as to cause the separate gases to condense, one after another, depending upon the

relation of their vapor pressure to the temperature of the coil and the pressure existing within the rectifier. The "Gasol" which is produced is a perfectly colorless and transparent liquid, which remains as a liquid at a temperature of 70 deg. cent. or lower, but which, at normal conditions of temperature, only exists in the form of a liquid when under a pressure in excess of 400 pounds per square inch. Any release of this pressure causes it to change at once into gas, this gas having the remarkably high calorific power when expanded to atmospheric pressure of 2,400 B. t. u. per cubic foot.

When it is remembered that the heating value of ordinary coal-gas is only about 600 B. t. u. per cubic foot, and manufactured oil gas is less than 650 B. t. u. per cubic foot, it

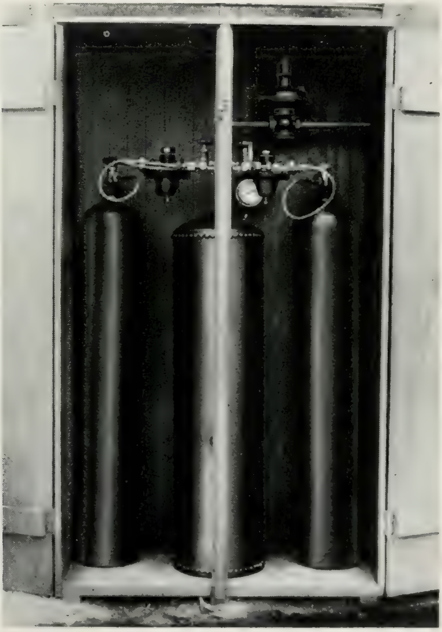

Fig. 231—LIQUEFIED GAS TANKS AND REGULATORS FOR HOUSE INSTALLATIONS

will be seen that the new gas has about four times the heat-producing capacity, when equal volumes are considered, of either coal-gas or manufactured oil-gas. In addition its flame temperature is much higher, being decidedly higher than the flame temperature of natural gas or any other of the common gases used for heating.

The flame temperature of ordinary natural gas burning in air is about 2,150 deg., and the flame temperature of ethane burning in air is about 2,205 deg. The flame temperature of the new gas is about 2,300 deg., and since the amount of light produced from the Welsbach mantle bears an important relation to the temperature of the flame, the reason is here seen for the remarkable brilliancy of the light produced by the new gas, which excels in this respect all gases previously known.

The liquid is distributed in steel bottles, about forty-four inches high and eight inches in diameter, each bottle holding forty pounds of the liquid gas, and producing the equivalent in heating power of somewhat over 2,000 cubic feet of ordinary coal gas.

The experimental development of "Gasol" has been going on for more than a year, and its commercial use dates back a few months. It is now being used in the lighting of country dwellings, where the only care given to it is the exchange of bottles as an old bottle becomes empty (usually about one a month), and in actual practice in the lighting of country homes this gas is proving to be remarkably well suited to such use. The light which it gives with the inverted Welsbach mantle is superior to the light which can be produced from either natural or coal gas. For cooking, the gas is also very satisfactory, giving a small but intensely hot flame, free from even the slightest disposition to soot.

PART SEVENTEEN

Power

Horse Power—The use of the term "horse power" as indicating the measure of an engine's work came naturally from the fact that the first engines were built to do work that had formerly been performed by horses. John Smeaton, who built atmospheric engines before Bolton and Watt placed their more complete machines upon the market, had valued the work done by a strong horse as being equivalent to lifting a weight of 20,000 pounds one foot high in one minute. When Bolton and Watt began to bid for public favor, they agreed to place their engines "for a value of one-third part of the coals which are saved in its use." They also increased the value of the "horse power" to 33,000 pounds, so that their engines were half again as powerful for their rated power as those of their competitors. In this way they established the value of horse power.

The following are the value of a horse power:

33,000 foot pounds per hour.

550 foot pounds per minute.

2545 thermal units per hour.

42.42 thermal units per minute.

The horse power of a boiler depends upon its capacity for evaporation. The evaporation of thirty pounds of water from 100 deg. fahr. into steam at 70 pounds gauge pressure (equaling 34½ pounds from and at 212 deg. fahr.) is equal to a horse power.

To find the mean effective pressure of a simple steam engine, using steam at an initial pressure of 80 pound gauge,

divide the length of cut-off by the total length of the stroke, both in inches, and take the mean effective pressure from the following table:

Cut-off % of stroke	.10	.15	.20	.25	.30	.35	.40	.45	.50
M. E. P. lb. per sq. in.	18	27	35	42	48	53	57	61	64

Super-heated steam is steam which has a greater temperature than that due to its pressure.

To determine the heating surface in the tubes of any boiler, multiply the number of feet of the tubes by the decimal .523 for 2-inch; .654 for 2½-inch; .785 for 3-inch; .916 for 3½-inch; and by 1.047 for 4-inch.

Steam—Steam is an elastic fluid generated by the action of heat upon water.

Steam, when separated from water, from which it is generated, follows the law of all other gases, expanding $\frac{1}{460}$ of its volume for each additional degree of heat, the pressure remaining the same; and, while the temperature remains the same, the pressure is in inverse proportion to the volume.

The temperature of the steam is equal to that of the water from which it is formed, and its elastic force is equal to the pressure under which it is formed.

Total heat of steam at 212 deg. fahr. is 1150 B. t. u.

Latent heat of steam is found by subtracting its sensible heat (called heat of the liquid) from the total heat, and is equal to 970.4 B. t. u. at 212 deg. fahr. or 14.7 lb. atmospheric pressure.

Latent heat of steam is composed of two elements—the heat required to evaporate the water into steam at the same temperature and pressure, and that necessary to do the

external work required by the steam to make room for itself against the pressure of the surrounding steam or atmosphere. It is not evidenced by any increase in temperature.

To find the quantity of water required to condense a given quantity of steam, substract the heat of the liquid at the temperature of the hot well from the total heat of the steam to be condensed. Then divide this difference by the difference in temperature between the hot well and the injection water, and multiply the quotient by the number of pounds of steam to be condensed. The result will be the weight of injection water required.

Steam Horse Power—The amount of water which a boiler will evaporate at an economical rate in an hour, divided by the above quantity, is its commercial horse power.

A unit of evaporation is the heat required to evaporate a pound of water from and at 212 deg. fahr. and is equal to 970.4 thermal units.

A thermal unit is the amount of heat required to raise a pound of water a fahrenheit degree in temperature at the point of maximum density, namely, 39 deg. fahr.

One thermal unit is equivalent to 778 foot pounds. The horse power of engines varies directly as the product of the piston area, piston speed, and mean effective pressure. Hence with the same m. e. p., the power of engines varies directly as their piston speed, and as the square of the diameter.

To Find Horse Power of a Steam Engine—To find the horse power of a steam engine, multiply the diameter of the piston in inches by itself, and this result by .7854, which will give the area of the piston in square inches. Multiply the area so found by the speed of the piston in feet per minute; or, if the speed is taken in inches, divide the product by 12, after multiplying. (Speed of piston is found by multiplying twice the length of stroke by the number of revolutions per minute.) Multiply speed of piston by the mean effective

TABLE OF AREAS OF CIRCLES

DIAM. INCH.	AREA	DIAM. INCH.	AREA	DIAM. INCH.	AREA	DIAM. INCH.	AREA
⅛	.0123	7¾	47.17	18½	268.80	37½	1104.5
¼	.0491	8	50.27	19	283.53	38	1134.1
⅜	.110	8¼	53.46	19½	298.65	38½	1164.2
½	.196	8½	56.75	20	314.16	39	1194.6
⅝	.307	8¾	60.13	20½	330.06	39½	1225.4
¾	.442	9	63.62	21	346.36	40	1256.6
⅞	.601	9¼	67.20	21½	363.05	40½	1288.2
1	.785	9½	70.88	22	380.13	41	1320.3
1⅛	.994	9¾	74.66	22½	397.61	41½	1352.7
1¼	1.227	10	78.54	23	415.48	42	1385.4
1⅜	1.485	10¼	82.52	23½	433.74	42½	1418.6
1½	1.767	10½	86.59	24	452.39	43	1452.2
1⅝	2.074	10¾	90.76	24½	471.44	43½	1486.2
1¾	2.405	11	95.03	25	490.87	44	1520.5
1⅞	2.761	11¼	99.40	25½	510.71	44½	1555.3
2	3.142	11½	103.87	26	530.93	45	1590.4
2¼	3.976	11¾	108.43	26½	551.55	45½	1626.0
2½	4.909	12	113.10	27	572.56	46	1661.9
2¾	5.940	12¼	117.86	27½	593.96	46½	1698.2
3	7.069	12½	122.72	28	615.75	47	1734.9
3¼	8.296	12¾	127.68	28½	637.94	47½	1772.1
3½	9.621	13	132.73	29	660.52	48	1809.6
3¾	11.05	13¼	137.89	29½	683.49	48½	1847.5
4	12.57	13½	143.14	30	706.86	49	1885.7
4¼	14.19	13¾	148.49	30½	730.62	49½	1924.4
4½	15.90	14	153.94	31	754.77	50	1963.5
4¾	17.72	14¼	159.48	31½	779.31	50½	2003.0
5	19.64	14½	165.13	32	804.25	51	2042.8
5¼	21.65	14¾	170.87	32½	829.58	51½	2083.1
5½	23.76	15	176.71	33	855.30	52	2123.7
5¾	25.97	15¼	182.65	33½	881.41	52½	2164.8
6	28.27	15½	188.69	34	907.92	53	2206.2
6¼	30.68	15¾	194.83	34½	934.82	53½	2248.0
6½	33.18	16	201.06	35	962.11	54	2290.2
6¾	35.79	16½	213.82	35½	989.80	54½	2332.8
7	38.49	17	226.98	36	1017.88	55	2375.8
7¼	41.28	17½	240.53	36½	1046.3	55½	2419.2
7½	44.18	18	254.47	37	1075.2	56	2463.0

(average) pressure of steam upon the piston which can only be determined by applying the indicator), and divide the product by 33,000, which gives the actual horse power.

Directions for Determining the Correct Setting of Engine Valves—*First*, equalize travel in steam chest by turning eccentric on shaft so throw is extreme one way, measuring the port opening; then turn eccentric extreme travel opposite, measuring port opening the same. If any difference, divide it up by lengthening or shortening the valve rod or eccentric rod.

After port openings are equal at both ends, turn crank on dead center; then turn eccentric on shaft so valve opens the port at the end of cylinder where piston is located, about 1-16 opening or lead. Fasten eccentric to shaft; then turn on the other dead center, when opening or lead should be the same.

In determining which way an engine is to run, bear in mind the crank pin always follows the throw of the eccentric.

Electrical Horse Power—The quantity of electricity flowing in a wire per second is measured in units called the ampere. The electrical pressure producing the flow is measured in volts, while the power an electrical current is capable of producing is equal to the product of amperes and volts and is measured in units called the watt. One watt is equal to one ampere multiplied by one volt. A kilowatt is 1000 watts.

The same work can be done with great current strength and low e. m. f. or with small current and high e. m. f. For instance, 100 amperes, times 10 volts, equals 1000 watts; or 10 amperes, times 100 volts, equals 1000 watts.

One electrical horse power equals 746 watts; hence, the electrical work of a dynamo may be expressed:

$$\text{h. p.} = \frac{\text{amperes} \times \text{volts}}{746}$$

The mechanical horse power necessary to drive a dynamo is generally ten to twenty per cent. higher than the electrical horse power yielded by the dynamo.

For Every-day Use in an Engine Room—To find diameter of cylinder for a given power:

Multiply horse power of engine by 33,000. Divide product by the product of cylinder area x steam pressure x piston speed in feet per minute.

Rule for finding contents in cubic feet of a cylinder of any given diameter.

Multiply the square of diameter in inches by .7854 and this product by length of stroke in inches. Divide last product by 1728, and the result is contents of cylinder in cubic feet.

The diameter of the valve rod should be 1-10 to 1-12 of the cylinder diameter, or from 1-350 to 1-300 of unbalanced area of slide valve. This last is considering the valve as a piston. Steel rods, of course, will bear being made smaller.

Don't depend too much upon the glass gauge, but try the cocks often enough to keep your hand in in telling the height of water by them. If a gauge cock has a tendency to leak, fix it thoroughly; if you do not you will neglect to use it for fear of the work which you may have to stop the leak after using.

Safety valves should be allowed to blow straight out into the room and should not be hitched on to a leading pipe which may allow water to stand on the valve, increasing its weight, or be liable to freeze if the boiler is laid up. When the valve blows into the room it will be known when steam is escaping, whether from leakage or over pressure.

The economy of an engine should always be rated by the amount of steam or water which it consumes per horse power per hour. The amount of coal burnt per horse power per hour involves the economy of the whole plant, and is

not a measure of the performance of the engine taken independently.

Horizontal engines, when practicable, should be run over rather than under, as the thrust will then come downward upon the foundation rather than upon the caps of the boxes and the upper guides.

In calculating horse powers of steam boilers, consider for:

Tubular boilers, 15 square feet of heating surface, equivalent to 1 horse power.

Portable boilers, 12 square feet of heating surface, equivalent to 1 horse power.

Cylinder boilers, 10 square feet of heating surface, equivalent to 1 horse power.

Fig. 232.—BOILER INSTALLATION.

PART EIGHTEEN

MISCELLANEOUS

CAPACITIES OF OIL LINES—CAPACITIES OF TANKS —SPECIFIC GRAVITIES OF LIQUIDS—WEIGHT AND TENSILE STRENGTH OF WOOD, IRON—WEIGHT OF ROUND IRON AND STEEL RODS—MELTING POINT OF METALS—WOOD FUEL EQUIVALENTS—CONVERSION TABLES, METRIC TO U. S.—NATURAL GAS ASSOCIATION.

Tank for Separating Gas from Oil Flowing from Well—Tanks are often used on oil leases showing large quantities of gas where the oil flows or is pumped. The gas taken from the oil is of first-class quality to run a gas engine at the power house, or could be "squeezed" to extract the gasoline,

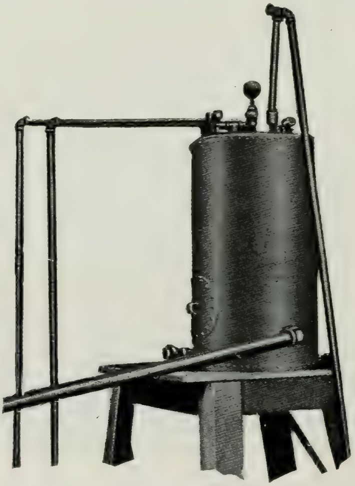

Fig. 233 AUTOMATIC OIL AND GAS SEPARATOR

provided there is a sufficient quantity of gas to make it pay. The separating tank should be set high enough to allow the oil, after separation, to flow freely to the regular oil tanks.

Fig. 234—A BURNING OIL WELL IN THE CADDO OIL FIELD (LA.)

Number of Barrels ($31\frac{1}{2}$ Gallons) Contained in Tanks

Diameter in Ft.	Depth in Feet: 5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5	23.3	28.0	32.7	37.3	42.0	46.7	51.3	56.0	60.7	65.3	70.0	74.7	79.3	84.0	88.7	99.3
6	33.6	40.3	47.0	53.7	60.4	67.1	73.9	80.6	87.3	94.0	100.7	107.4	114.1	120.9	127.6	134.3
7	45.7	54.8	64.0	73.1	82.2	91.4	100.5	109.7	118.8	127.9	137.1	146.2	155.4	164.5	173.6	182.8
8	59.7	71.7	83.6	95.5	107.4	119.4	131.3	143.2	155.2	167.1	179.0	191.0	202.9	214.8	226.8	238.7
9	75.5	90.6	105.7	120.9	136.0	151.1	166.2	181.3	196.4	211.5	226.6	241.7	256.8	272.0	287.0	302.1
10	93.2	111.9	130.6	149.2	167.9	186.5	205.1	223.8	242.4	261.1	289.8	298.4	317.0	335.7	354.3	373.0
11	112.8	135.4	158.0	180.5	203.1	225.7	248.2	270.8	293.4	315.9	338.5	361.1	383.6	406.2	428.8	451.3
12	134.3	161.1	188.0	214.8	241.7	268.6	295.4	322.3	349.1	376.0	402.8	429.7	456.6	483.4	510.3	537.1
13	157.6	189.1	220.6	252.1	283.7	315.2	346.7	378.2	409.7	441.3	472.8	504.3	535.8	567.3	593.0	630.4
14	182.8	219.3	255.9	292.4	329.0	365.5	402.1	438.6	475.2	511.8	548.3	584.9	621.4	658.0	694.5	731.1
15	209.8	251.8	293.7	335.7	377.7	419.6	461.6	503.5	545.5	587.5	629.4	671.4	713.4	755.3	797.3	839.3
16	238.7	286.5	334.2	382.0	429.7	477.4	525.2	572.9	620.7	668.2	716.2	773.9	811.6	859.4	907.1	954.9
17	269.5	323.4	377.3	431.2	485.1	539.0	592.9	646.8	700.7	754.6	808.5	862.4	916.3	970.2	1024.1	1078.0
18	302.1	362.6	423.0	483.4	543.8	604.3	667.7	725.1	785.5	846.0	906.4	966.9	1027.2	1087.7	1148.1	1208.5
19	336.6	404.0	471.3	538.6	605.9	673.3	740.6	807.9	875.2	942.6	1009.9	1077.2	1144.6	1211.9	1279.2	1346.5
20	373.0	447.6	522.2	596.8	671.4	746.0	820.6	895.2	969.8	1044.4	1119.0	1193.6	1268.2	1342.8	1417.4	1492.0
21	411.2	493.5	575.7	658.0	740.2	822.5	904.7	987.0	1069.2	1151.5	1233.7	1315.9	1398.2	1480.4	1562.7	1644.9
22	451.3	541.6	631.9	722.1	812.4	902.7	992.9	1083.2	1173.5	1263.7	1354.0	1444.3	1534.5	1624.8	1715.1	1805.3
23	493.3	592.0	690.6	789.3	887.9	986.6	1085.2	1183.9	1282.6	1381.2	1479.9	1578.5	1677.2	1775.9	1874.5	1973.2
24	537.1	644.5	752.0	859.4	966.8	1074.2	1181.7	1289.1	1396.5	1503.9	1611.4	1718.8	1826.2	1933.6	2041.1	2148.5
25	582.8	699.4	815.9	932.5	1049.1	1165.6	1282.2	1398.7	1515.3	1631.9	1748.4	1865.0	1981.6	2098.1	2214.7	2321.2
26	630.4	756.5	882.5	1008.6	1134.7	1260.8	1386.8	1512.9	1639.0	1765.1	1891.1	2017.2	2143.3	2269.4	2395.4	2521.5
27	679.8	815.8	951.7	1087.7	1223.6	1359.6	1495.6	1631.5	1767.5	1903.4	2039.4	2175.4	2311.3	2447.3	2583.2	2719.2
28	731.1	877.3	1023.5	1169.7	1316.0	1462.2	1608.7	1754.6	1900.8	2047.1	2193.3	2339.5	2485.7	2631.9	2778.1	2924.4
29	784.2	941.1	1097.9	1254.8	1411.6	1568.5	1725.3	1882.2	2039.0	2195.9	2352.7	2509.6	2668.4	2823.3	2980.1	3137.0
30	839.3	1007.1	1175.0	1342.8	1510.7	1678.5	1846.4	2014.2	2182.0	2343.9	2517.8	2685.6	2853.5	3021.3	3189.2	3357.0

Fig. 235—SAME WELL AS Fig. 234.

The fire was extinguished by digging a tunnel to the well at a safe depth, bolting a saddle on the casing and laying a lead line off to a safe distance, after which the casing was tapped with the aid of smaller line used as a drill stem working through the lead line. The gate on top of the casing was partially closed at the time the well caught fire which created a back pressure and assisted in forcing the oil through lead line

Melting Point and Expansion of Metals

Substance	Melting Point	Lineal Expansion of Metals
	Deg. fahr.	Produced by raising their temperature from 32 to 212 deg.
	Kent	
Aluminum	1247 (1157)	
Bronze	1652 (1692)	
Copper	2102 (1929)	One part in 581
Gold	2192 (1913)	" " " 682
Cast Iron	1922 to 2382	" " " 812
Wrought Iron	2732 to 2912	" " " 812
Lead	(618)	" " " 351
Platinum	3227	" " " 1100
Silver	1832 (1733)	" " " 524
Steel	2372 to 2552	" " "
Tin	540 (442)	" " " 403
Zinc	786 (779)	" " " 322

Beaume Scale and Specific Gravity Equivalent—The instruments used are a hydrometer and a standard thermometer. The hydrometer, which is a glass column marked with graduations from 10 to 100, was invented by Antoine Beaume, a French chemist, and the scale on the instrument has always borne his name. The hydrometer, when placed in a jar or a bottle of oil, sinks to the point on the scale which indicates the gravity in degrees Beaume. The basis of temperature for testing oil is 60 deg. fahr., and for oil at a greater or less temperature variations, must be calculated. Hydrometers are usually provided with a special scale for figuring temperature variations. The specific gravity is found by dividing 140 by 130 plus the Beaume degrees. For example: if the hydrometer registers 30 deg., this added to 130 equals 160, which divided into 140, shows specific gravity .875 deg.

Following is a table showing Beaume degrees, specific gravity and weight per gallon of oil of 60 deg. fahr:

Beaume Degrees	Specific Gravity	Lb. in Gallon	Beaume Degrees	Specific Gravity	Lb. in Gallon	Beaume Degrees	Specific Gravity	Lb. in Gallon
10	1.0000	8.33	37	0.8383	6.99	64	0.7216	6.03
11	0.9929	8.27	38	0.8333	6.95	65	0.7179	6.00
12	0.9859	8.21	39	0.8284	6.91	66	0.7142	5.97
13	0.9790	8.16	40	0.8235	6.87	67	0.7106	5.94
14	0.9722	8.10	41	0.8187	6.83	68	0.7070	5.91
15	0.9655	8.05	42	0.8139	6.80	69	0.7035	5.88
16	0.9589	7.99	43	0.8092	6.76	70	0.7000	5.85
17	0.9523	7.94	44	0.8045	6.72	71	0.6965	5.82
18	0.9459	7.88	45	0.8000	6.68	72	0.6930	5.79
19	0.9395	7.83	46	0.7954	6.64	73	0.6896	5.77
20	0.9333	7.78	47	0.7909	6.60	74	0.6863	5.74
21	0.9271	7.73	48	0.7865	6.57	75	0.6829	5.71
22	0.9210	7.68	49	0.7821	6.53	76	0.6796	5.68
23	0.9150	7.63	50	0.7777	6.49	77	0.6763	5.65
24	0.9090	7.58	51	0.7734	6.46	78	0.6730	5.63
25	0.9032	7.54	52	0.7692	6.42	79	0.6698	5.60
26	0.8974	7.49	53	0.7650	6.39	80	0.6666	5.57
27	0.8917	7.44	54	0.7608	6.36	81	0.6635	5.55
28	0.8860	7.39	55	0.7567	6.32	82	0.6604	5.51
29	0.8805	7.34	56	0.7526	6.29	83	0.6573	5.48
30	0.8750	7.29	57	0.7486	6.26	84	0.6542	5.45
31	0.8695	7.25	58	0.7446	6.22	85	0.6511	5.42
32	0.8641	7.21	59	0.7407	6.19	86	0.6481	5.40
33	0.8588	7.16	60	0.7368	6.16	87	0.6451	5.38
34	0.8536	7.12	61	0.7329	6.13	88	0.6422	5.36
35	0.8484	7.07	62	0.7290	6.10	89	0.6392	5.33
36	0.8433	7.03	63	0.7253	6.07	90	0.6363	5.30

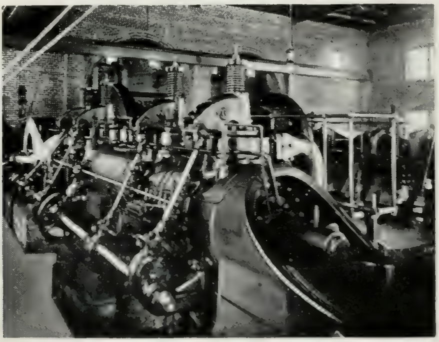

Fig. 236.

Specific Gravities of Liquids at 60 Deg. Fahr.

Liquid	Specific Gravity	Liquid	Specific Gravity
Rigolene	.625	Olive Oil	.92
Naptha	.690	Rape Oil	.92
Naptha No. 2	.707	Linseed Oil	.94
Sulphuric Ether	.720	Water	1.00
Alcohol (pure)	.794	Muriatic Acid	1.20
Refined Petroleum	.805	Nitric Acid	1.22
Alcohol (95%)	.816	Sulphuric Acid	1.85
Turpentine	.870	Mercury	13.58

Weight and Tensile Strength of Wood, Iron and Other Materials

Material	Weight per Cubic Foot Pounds	Tensile Strength Pounds per Square Inch
White Ash	38	11000
Hickory	53	12800
Chestnut	41	10500
Hemlock	25	8700
White Oak	48	10500
Red Oak	40	10000
Yellow Pine	45	12600
Oregon Pine	40	12000
Norway Pine	34½	11000
White Pine	25	10000
Redwood	...	7000
Spruce	125	10000
Whitewood	...	8500
Walnut	38	9286
Cast Iron	450	15000 to 24000
Malleable Iron	450	25000 to 35000
Copper	550	20000 to 30000
Aluminum	167	15000 to 24000
Wrought Iron	485	40000 to 50000
Wrought Steel	490	60000 to 80000
Iron Pipe	....	35000 to 45000
Steel Pipe	....	50000 to 65000
Cement	75 to 90	350
Sand	115	....
Limestone	168	....

Weights of Round Iron and Steel per Lineal Foot in Pounds

Size in Inches	Iron	Steel
1/4	.164	.167
5/16	.256	.261
3/8	.368	.375
7/16	.501	.511
1/2	.654	.667
9/16	.828	.845
5/8	1.023	1.043
11/16	1.237	1.262
3/4	1.473	1.502
7/8	2.004	2.044
1	2.618	2.67
1 1/8	3.313	3.379
1 1/4	4.091	4.173
1 3/8	4.95	5.049
1 1/2	5.09	6.008
1 5/8	6.913	7.051
1 3/4	8.018	8.078
1 7/8	9.204	9.388
2	10.470	10.679
2 1/8	11.820	12.056
2 1/4	13.250	13.515
2 3/8	14.770	15.065
2 1/2	16.36	16.69
2 5/8	18.04	18.40
2 3/4	19.8	20.2
2 7/8	21.64	22.07
3	23.56	24.03

Conversion Tables

COMPOUND UNITS

Metric to U. S.

1 kilogram per meter=0.6720 lb. per foot.
1 kilogram per sq. centimeter=14.223 lb. per sq. inch.
1 kilogram per sq. meter=0.2048 lb. per sq. foot.
1 kilogram per cubic meter=0.0624 lb. per cu. ft.
1 kilogram-meter=7.233 foot pounds.
1 chevel vapeur (metric h. p.)=0.986 horsepower.
1 kilowatt=1.340 horsepower.
1 kilo. per chevel=2.235 lb. per h. p.

U. S. to Metric

1 lb. per ft.=1.4882 kilograms per meter.
1 lb. per sq. inch=0.0703 kilograms per sq. centimeter.

U. S. to Metric—Continued

1 lb. per sq. ft.=4.8825 kilograms per sq. meter.
1 lb. per cu. ft.=16.0192 kilograms per cu. meter.
1 foot pound=.01383 kilogram-meter.
1 horsepower=1.014 chevel-vapeur (metric h. p.)
1 horsepower=0.746 kilowatt.
1 lb. per horse power=0.447 kilos per chevel.

MEASURES OF HEAT.

Heat Intensity

Temp. Centigrade (temp. fahr.—32 deg.) 5/9.
Temp. fahrenheit (temp. C. x 9/5=32 deg.)

Heat Quantity

A kilogram calorie=3.968 British thermal units.
A pound calorie=1.8 British thermal units.
A British thermal unit=0.252 kilogram calorie.
A British thermal unit=0.555 pound calorie.

MEASURES OF VOLUME AND CAPACITY

Metric to U. S.

1 cu. centimeter=0.061 cu. inch.
1 cu. meter=35.316 cu. feet.
1 cu. meter=1.308 cu. yards.
1 liter 1 cu. decimeter=61.023 cu. inch.

Liquid Measure

1 liter=1.0567 quart.
1 liter=0.2642 gallon.
1 cu. meter=264.17 gallon.

Dry Measure

1 liter=0.908 quart.
1 hectoliter=2.8375 bushels.

U. S. to Metric

1 cu. inch=16.39 cu. centimeters.
1 cu. ft.=0.0283 cu. meter.
1 cu. yd.=0.7645 cu. meter.
1 cu. ft.=28.32 liters.

Liquid Measure

1 quart=0.9463 liters.
1 gallon=3.7854 gallons.
1 gallon=0.0038 cu. meter.

Dry Measure

1 quart=1.1013 liters.
1 bushel=0.3524 hectoliters.

WEIGHTS

Metric to U. S.

1 milligram=0.0154 grain.
1 gram=15.432 grain.
1 kilogram=2.2046 lb. (avoir.)
1 metric ton=1.1023 net tons.
1 metric ton=0.9842 gross tons.

U. S. to Metric

1 grain=64.80 milligrams.
1 grain=0.0647 gram.
1 lb. (avoir.)=0.4536 kilogram.
1 net ton=0.9076 metric ton.
1 gross ton=1.0161 metric ton.

MEASURES OF LENGTH

Metric to U. S.

1 millimeter = 0.03937 inch.
1 centimeter = 0.3937 inch.
1 meter =39.37 inch.
1 meter = 3.2808 feet.
1 kilometer = 0.6214 mile.

U. S. to Metric

1 inch =25.4 millimeters.
1 inch = 2.54 centimeters.
1 inch = 0.0254 meter.
1 foot = 0.3048 meter.
1 mile = 1.609 kilometers.

MEASURES OF SURFACE

Metric to U. S.

1 sq. millimeter= 0.00155 sq. inch.
1 “ centimeter= 0.155 “ “
1 “ meter =10.764 “ ft.
1 “ “ = 1.196 “ yds.
1 hectare = 2.471 acres.
1 “ = 0.00386 sq. mile.
1 sq. kilometer = 0.3861 “ “

U. S. to Metric

1 sq. inch =645.14 sq. millimeters.
1 “ “ = 6.452 “ centimeters.
1 “ foot = 0.0929 “ meter.
1 “ yard = 0.8361 “ “
1 acre = 0.4047 hectares.
1 sq. mile =259.00 “
1 “ “ = 2.59 sq. kilometers.

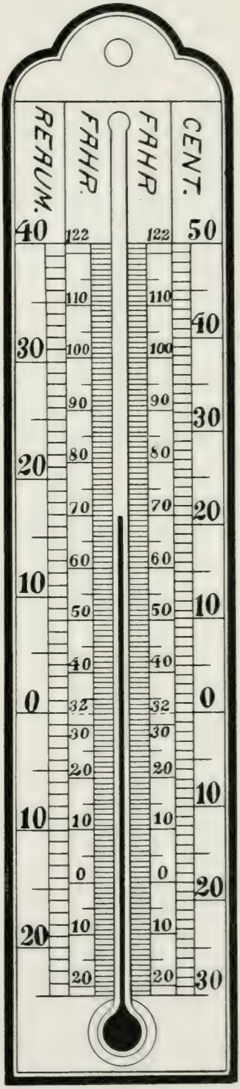

Fig. 237

The Natural Gas Association—The first promoters of the Natural Gas Association of America were C. W. Sears, K. M. Mitchel and M. M. Sweetman. The first organization meeting was held at the Midland Hotel in Kansas City, Mo., February 20, 1906, and the following officers were duly elected:

President, K. M. Mitchel, St. Joseph, Mo.
Vice-President, M. M. Sweetman, Kansas City, Mo.
Treasurer, C. H. Pattison, Kansas City, Mo.
Secretary, J. H. Dunkel, Lawrence, Kas.

The ssAociation started with 30 charter members. The first annual meeting was held at the Midland Hotel, Kansas City, Mo., June 12–13, 1906. Successive meetings have been held in Joplin, Mo., Kansas City, Oklahoma City, Pittsburg, Kansas City, Cleveland, O., St. Louis, Mo., the last at Cincinnati, O., in 1915.

There were about seven hundred members at the date of the last meeting.

The dues are: Active membership, $5.00 per year; junior membership, $3.00 per year.

INDEX

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